JANUARY TO DECEMBER

THE HAWAIIAN PLANTERS' RECORD

VOL. XLI

ORGAN OF THE EXPERIMENT STATION OF THE HAWAIIAN SUGAR PLANTERS' ASSOCIATION

HONOLULU

1937

HAWAIIAN SUGAR PLANTERS' ASSOCIATION

OFFICERS FOR 1937

TRUSTEES FOR 1937

EXPERIMENT STATION COMMITTEE

EXPERIMENT STATION STAFF

H. L. LYON, Director

ENTOMOLOGY

C. E. PEMBERTON, Executive Entomologist
R. C. L. PERKINS, Consulting Entomologist
O. H. SWEZEY, Consulting Entomologist
F. X. WILLIAMS, Associate Entomologist
R. H. VAN ZWALUWENBURG, Associate Entomologist
F. A. BIANCHI, Assistant Entomologist
J. S. ROSA, Laboratory Technician

PATHOLOGY

J. P. MARTIN, Pathologist
C. W. CARPENTER, Associate Pathologist
D. M. WELLER, Histologist

GENETICS

A. J. MANGELSDORF, Geneticist
C. G. LENNOX, Associate Geneticist
H. K. STENDER, In charge Kailua Substation
WILLIAM BRANDT, Field Assistant
A. DOI, Field Assistant
R. URATA, Field Assistant

AGRICULTURE

R. J. BORDEN, Agriculturist
J. A. VERRET, Consulting Agriculturist
R. E. DOTY, Associate Agriculturist
L. R. SMITH, Associate Agriculturist
K. H. BERG, Assistant Agriculturist
H. A. WADSWORTH, Irrigation Specialist
J. A. SWEZEY, Assistant in Irrigation
A. Y. CHING, Assistant in Cane Growth Studies

CHEMISTRY

F. E. HANCE, Chemist
L. E. DAVIS, Associate Chemist
F. R. VAN BROCKLIN, Associate Chemist
A. S. AYRES, Assistant Chemist
PAUL GOW, Assistant Chemist
Q. H. YUEN, Assistant Chemist
E. K. HAMAMURA, Assistant Chemist
P. E. CHU, Assistant Chemist
T. NISHIMURA, Assistant Chemist
L. L. SUTHERLAND, Clerk, Fertilizer Control

TECHNOLOGY

W. L. MCCLEERY, Technologist
W. R. MCALLEP, Consulting Technologist
RAYMOND ELLIOTT, Assistant Technologist
H. A. COOK, Assistant Technologist
FRED HANSSON, Assistant Technologist
W. S. FLESHMAN, Assistant Technologist
A. FABIUS, Assistant Technologist

BOTANY AND FORESTRY

H. L. LYON, Botanist and Forester
E. L. CAUM, Associate Botanist
L. W. BRYAN, Associate Forester (Hawaii)
G. A. MCELDOWNEY, Associate Forester (Oahu)
A. W. DUVEL, Associate Forester (Kauai)
COLIN POTTER, Nursery Superintendent

RESEARCH LABORATORIES

H. W. BRODIE, Research Associate
D. A. COOKE, Research Associate
U. K. DAS, Research Associate
CONSTANCE E. HARTT, Research Associate
H. P. KORTSCHAK, Research Associate
A. R. LAMB, Research Associate
A. H. CORNELISON, Research Assistant
ADA FORBES, Research Assistant
GORDON FURMIDGE, Research Assistant
DAVID TAKAHASHI, Research Assistant
T. TANIMOTO, Research Assistant
S. W. BURTON, Instrument Maker

ISLAND REPRESENTATIVES

F. C. DENISON (Oahu)
O. H. LYMAN (Hawaii)
D. S. JUDD (Maui)
J. W. ANDERSON (Kauai)

GENERAL

W. TWIGG-SMITH, Artist
A. R. GRAMMER, Office Manager
F. D. KENNEDY, Clerk
MABEL FRASER, Librarian
MARTHA WRIGHT, Assistant Librarian
WILLIAM SA NING, Superintendent of Grounds

TABLE OF CONTENTS

	Page
Cane Growth Studies	3
Notes on Sugar Cane in West Africa	7
Yams for Hawaiian Gardens—II	13
Evaluation of Nitrogen in Molasses	19
Summary of Laboratory Studies of Anomala, 1933-1935	25
The Synthesis of Sucrose by Excised Blades of Sugar Cane	33
The Availability of the Principal Nutrients in a Soil During the Crop-Growth Period	47
West African Notes	57
Sugar Prices	84
Phosphate Deficiency	87
Variation in the Nitrogen Content of Irrigation Water Carrying Dissolved Nitrogen Fertilizer	91
Better Planning for Field Experiments With Fertilizers	99
Impressions and Observations in East Africa	111
Soil and Plant Material Analyses by Rapid Chemical Methods—II	135
Sugar Prices	187
Comparative Irrigation Institutions in Hawaii and in Continental United States and Some Developments Under Them	191
Scientific Irrigation Management	199
The Value of Irrigation Water as a Factor in Interval Control	281
Sugar Prices	287
Present Trends	291
Fruit Fly Investigations in East Africa	299
Some Important Factors to Consider in Selecting Seedlings	307
Notes on a New Species of Pyrophorus Introduced Into Hawaii to Combat *Anomala Orientalis* Waterhouse	319
Absorption of Mineral Nutrients by Sugar Cane at Successive Stages of Growth	335
Chemical Analyses as an Aid in the Control of Nitrogen Fertilization	353
Trends in Irrigation Practice	385
Sugar Prices	410

ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XLI

FIRST QUARTER

Hawaiian-grown tubers of Tsukune, a form of the Chinese potato.

SECOND QUARTER

Plants at right received phosphate at time of planting; plants at left received no phosphate fertilizer. Age when photographed—six weeks.

THIRD QUARTER

Spillway of the Wahiawa Reservoir, largest reservoir in the Territory of Hawaii and chief source of irrigation water for the Waialua Agricultural Company, Ltd. Courtesy of A. A. Wilson.

Female adult of *Pyrophorus bellamyi* Van Zwal., a click beetle of recent introduction, whose wireworm larva is expected to aid in the control of Anomala and Adoretus grubs.

THE HAWAIIAN PLANTERS' RECORD

Vol. XLI FIRST QUARTER, 1937 No. 1

A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

The Effect of Sunlight on the Utilization of Nitrogen and Potash by H 109 Cane:

Another cane growth study has contributed further evidence which indicates that under conditions of reduced sunlight, sugar cane may not be able to utilize effectively the larger applications of nitrogen and potash fertilizers which are sometimes supplied in an effort to compensate for certain unfavorable growing conditions.

Notes on Sugar Cane in West Africa:

The important sugar cane pests are quite different in West Africa from those affecting the crop in Hawaii, but a few wide-spread, minor insects are common to both regions. Relatives of our Anomala and Adoretus occur (though not as pests of cane), but nothing encourages the hope that effective parasites of their grub stages are obtainable there.

Yams:

A second article dealing with a food crop of considerable economic importance is presented as a sequel to that appearing in the previous volume of the *Record*.

Evaluation of Nitrogen in Molasses:

Further studies concerned with the value of nitrogen in molasses as a partial substitute for commercial nitrogen fertilizer, verify our previous findings and indicate quite definitely that most likely it will not be economical to use this mill byproduct for the nitrogen which it carries.

Anomala Studies:

A correlation apparently exists between a soil's susceptibility to Anomala infestation and the figure obtained by dividing the ignition loss of the soil by its moisture equivalent. The lethal point for Anomala eggs with respect to soil moisture (a factor intimately associated with the ignition loss-moisture equivalent correlation) was found to be a very critical one, lying somewhere between 98.7 and 97.9 per cent relative humidity. Miscellaneous life history data are discussed.

The Synthesis of Sucrose by Excised Blades of Sugar Cane:

Excised leaf blades of the sugar cane plant can manufacture cane sugar in the dark when supplied with the simple sugars, glucose and fructose.

The Availability of the Principal Nutrients in a Soil During the Crop-Growth Period:

Both the natural and the imposed variations in the supply of available nutrients which have occurred in a soil supporting a normal crop throughout the entire period of its growth have been measured and are recorded especially for the benefit of those who are taking soil samples and interpreting the results of their soil analyses in terms of the principal fertilizer requirements for their sugar cane crop.

West African Notes:

The comparatively primitive agriculture of West Africa is so different from that of more advanced communities that its problems are of interest, even if offering few lessons to a more highly developed system. In spite of its crudity, the native agriculture suffices for the conditions under which millions of Africans live; that it can adapt itself to the needs of world commerce is shown by the existence of an enormous cocoa industry in the Gold Coast, which is essentially native in character. Natural advantages enable the West Coast to maintain its preeminence in certain products necessary to the white man, notably palm oil.

West Africa is the native home of numerous kinds of fruit flies, and is a rich field from which to obtain parasites useful in reducing the ravages of the Mediterranean fruit fly.

Cane Growth Studies

THE EFFECT OF SUNLIGHT ON THE UTILIZATION OF NITROGEN AND POTASH BY H 109 CANE

By R. J. Borden

On some of the sugar cane lands in these Islands the preponderance of cloudy days over sunny days is a matter of record and yet we do succeed in growing some good crops under such conditions. The results, however, are not always what we want them to be, nor are they seldom the same, even though we may have made no changes in the field practices for such lands. It is not altogether unlikely that the reason the results are dissimilar is because the weather conditions for successive crops are scarcely apt to be alike; hence, because sunlight is such a dominating weather factor, we are all interested in knowing more of its effects and influence on the other growth factors over which we do have more control.

In a previous study* concerned with climatic conditions, we found that cane which was grown under less favorable climatic influences (chiefly reduced sunlight) was unable to utilize our liberal applications of fertilizer. These liberal applications produced a gain over only one-fourth as much fertilizer, of 140 per cent on POJ 2878 cane yields without changing its quality ratio (8.3) when grown under the favorable Makiki climate, but under the less favorable (cloudy) Manoa conditions, this gain was only 40 per cent and the quality ratio accompanying this 40 per cent gain was increased from 8.7 to 12.5.

The present study (Project A-105 No. 81) was aimed to secure further information on the relationship between sunlight and two plant foods, nitrogen and potash, which we are sometimes apt to be quite liberal with, in our efforts to secure still better yields.

A well-mixed Manoa soil, low in both available nitrogen and potash, was used. It was potted in Mitscherlich pots and two uniform pregerminated shoots of H 109 cane planted therein. Ample phosphate fertilizer was furnished, and different amounts of nitrogen and of potash were provided—nitrogen fertilizer at the rate of 0, 150, 225 and 300 pounds per acre, and potash fertilizer at the rate of 0, 200, 300 and 400 pounds per acre. (Potash at 400 pounds per acre was supplied for all pots in the N series, and nitrogen at 300 pounds per acre was given to the pots in the potash series.) All treatments were in triplicate except the checks (no N and no K_2O) which were in duplicate. Three series were provided: one of these was grown continuously in full sunlight; a second series received direct sunlight from sunrise to mid-day only, while the third series was exposed to the direct sunlight from mid-day until sunset only. Thus we attempted to differentiate between the effect of (1) full sunlight vs. reduced sunlight, and (2) morning and afternoon direct light exposure, on the effective utilization of nitrogen and potash as measured by the relative amounts of dry matter produced from the initial applications that were supplied. The results are summarized in the following table and a discussion of the data follows:

---

*Borden, R. J., 1936. Cane Growth Studies—The Dominating Effect of Climate. *The Hawaiian Planters' Record*, 40:143-156.

EFFECT OF LIGHT ON THE UTILIZATION OF NITROGEN AND POTASH BY H 109 CANE

Differential Fertilizer Treatment (Rate per Acre)	Dry Yields (grams) In Full Sunlight	In Direct A. M. Sunlight	In Direct P. M. Sunlight	Per Cent Moisture in Cane Harvested Full Sun	A. M. Sun	P. M. Sun
No N.........	6.8± .6	5.4±1.5	6.6± .2	63.0	61.2	55.7
150 lb N.	82.3±3.1	76.1±1.9	74.4±2.5	66.2	70.1	69.7
225 lb N.	128.5±5.3	109.5±2.3	111.7±3.5	69.8	71.6	72.8
300 lb N.	173.1±2.2	134.0± .5	135.5±3.5	69.4	72.9	72.8
No K_2O	107.3±1.5	100.3±1.6	90.8±2.9	64.7	67.4	70.1
200 lb K_2O ...	144.9±1.4	122.9±5.8*	133.2±2.9*	68.9	71.8	70.1
300 lb K_2O ...	147.9±1.4	122.9±5.4	137.3±3.4	68.8	73.0	72.9
400 lb K_2O ...	173.1±2.2	134.0± .5	135.5±3.5	69.4	72.9	72.8

In view of the fact that all plants had stopped growing and showed definite symptoms of acute nitrogen deficiency when they were harvested at the age of four months, we feel justified in assuming that any further increase in weight that might have taken place would have been so small that it would have had little or no effect on our interpretation of the data which we obtained. Hence we offer the following discussion:

Differences between the morning sun and the afternoon sun were not demonstrated in the final results, although during the progress of the test, our observations had indicated that more growth was being made by the plants which were receiving the afternoon sun.

Dry weights were greater from cane grown in full sunlight, although here too our observations had indicated that stalk and leaf elongation were better in the afternoon sunlight series.

When no nitrogen was supplied all growth was very poor and there were no apparent differences in dry weights secured. When a small application of nitrogen (150 pounds per acre) was furnished, a gain of 11 times the dry-weight-without-nitrogen was obtained in both the full-sunlight series and in the reduced-sunlight series (A. M. and P. M. series averaged); however, a second similar 150 pounds per acre increment of nitrogen produced 13 and 10 times the dry-weight-without-nitrogen respectively for the full-sunlight and reduced-sunlight series, thus indicating at least that the plants grown in reduced light conditions were not able to utilize the heavier applications of nitrogen as effectively as they might have if more sunlight had been available.

This apparent inability of the plants grown under a reduced amount of light to effectively utilize the heavier applications of plant food is even more clearly shown from the results of the potash series. The first 200 pounds per acre potash increment gave very similar gains in dry weight (35 and 34 per cent respectively) for both the full-sunlight and the partial-sunlight series, but gains for potash stopped with this 200-pound application when the cane was grown under reduced light, while the plants that were grown in full sunlight gave a 20 per cent further increase in yield for a second 200-pound potash increment.

* Gains above this are not significant in this sunlight series.

Some very interesting moisture relationships are indicated. Disregarding the plants which received no nitrogen because they were barely alive at the time of harvest, it is apparent from the percentage moisture figures that the plants grown in full sunlight were less succulent than either of the series grown under reduced light. These same figures also show that the percentage of moisture in the plants at harvest was influenced by the fertilization they had received, being higher in the cane which had received the larger amounts of nitrogen and of potash than in the plants which had been given the minimum application.

From these results it may be postulated that a large part of the reason for poor juices in cane from areas that have inferior light conditions is due to the higher moisture content of such cane, and that since the moisture content is greater when liberal amounts of nitrogen and potash are furnished, better juices might be secured if we were not too liberal with these plant foods under such conditions. Furthermore, inasmuch as it is indicated that the "law of diminishing returns" is effective on cane yields sooner with lower amounts of potash and nitrogen used under reduced light conditions, it would appear that actual economies may be secured through adjustments of fertilizer applications with respect to the expected and prevalent sunlight conditions that will be likely to affect each crop. Apparently it would be a fallacy to expect that better results would be secured from lands that are subject to continued periods of overcast or cloudy weather, by boosting the nitrogen and potash applications in an attempt to compensate for the shortage of sunlight.

Notes on Sugar Cane in West Africa

By R. H. Van Zwaluwenburg

While in West Africa from November 9, 1935, to July 28, 1936, the writer had several opportunities to make observations on sugar cane. West of the Belgian Congo there is no commercial sugar industry. In the Congo there is said to be a plantation between Matadi and Leopoldville, but lack of time prevented a visit there. In the next colony to the south, Angola (Portuguese West Africa), there are seven commercial plantations; observations made on one of them, in June, have been placed on record in the Station files.

A noble cane, greenish in color, is common in dooryard plantings in Sierra Leone and Nigeria; it is grown for chewing, and is usually on sale in the native markets. Its habit of growth suggests Yellow Caledonia, a variety which it definitely is not. What is apparently the same variety was seen also in Liberia, Ivory Coast, and Gold Coast. In the French Cameroons apparently the same cane occurs, as well as a reddish variety. Nowhere are varietal names in use; all are simply "sugar cane".

Natal Uba and POJ 2878 are the principal varieties grown commercially in Angola.

Diseases

Only in Angola were definite disease symptoms seen on sugar cane. At Catumbela, near Lobito, typical mosaic symptoms were observed on large areas of Uba. On the same plantation were numerous areas of growth failure, some of considerable extent due, according to the plantation chemist, to heavy salt concentrations in the low flats near the sea, on which the cane grows.

Pests

Birds:

The most conspicuous pest of cane in Sierra Leone is the "village weaver" or "palm" bird (*Ploceus cucullatus cucullatus*) which strips the leaves of sugar cane, bananas and palms with which to weave its hanging nests. The nests are placed preferably on the tips of slender branches and twigs, but since the bird is gregarious and usually crowds a large number of nests into a single tree, even when others are available nearby, many individuals are forced to build their nests on comparatively thick branches where eggs and young are probably accessible to marauding rats. The village weaver is about the size of our mynah, or slightly smaller, its black plumage conspicuously marked with bright yellowish patches on the wings. It was observed also in Liberia, Ivory Coast, Gold Coast, and Nigeria, while nests of a similar, but perhaps different species, were seen in the Cameroons. A second species, *P. castaneofuscus* Less., also occurs in Sierra Leone, but is said not to be a pest. The manner in which *cucullatus* gathers cane leaves is interesting: after snipping the leaf blade at the base to about the midrib, it flies off, tearing the leaf longitudinally until it finally tears loose at the tip. The damage incurred is often severe; I have seen large Raphia palm trees completely defoliated by it, with little left but bare midribs.

Homoptera:

The commonest and most widespread insect on sugar cane in Sierra Leone was the cercopid *Locris maculata* Fab., which feeds also upon corn and grasses in general. It occurs also in Gold Coast, Nigeria, and French Cameroons. Ernest Hargreaves, the entomologist at Njala, Sierra Leone, knows of no parasites of this insect in his region.

Mr. Hargreaves in his very complete list of Sierra Leone economic insects, includes the following additional homoptera as attacking sugar cane:

Family		Additional hosts
Derbidae	*Diostrombus dilatata West.*	Banana, coconut, oil palms.
Derbidae	*Proutista fritillaris Boh.*	Coconut, oil and *Sabal blackburniana* palms, guava, grasses.
Lophopidae	*Elasmoscelis trimaculata Wlk.*	Grasses.

In addition, Mr. Hargreaves has taken, on sugar cane at Njala, a cercopid (probably *Poöphilus adustus* [Wlk.], an undetermined lophopid (*Lophops servillei* [Spin.] ?), and a scolytid beetle.

At Catumbela, Angola, a pink mealybug (presumably *Trionymus sacchari* Zehnt.) was widespread on sugar cane, with a dipterous maggot predaceous upon it. A single colony of what appears to be *T. boninsis* Kuwana (the gray mealybug) was seen on the same plantation; the same insect was common on cane at Njala, Sierra Leone.

A small blackish lophopid (*Elasmoscelis cimicoides* Spin.) could be found in small numbers throughout the Catumbela plantation.

Lepidoptera:

Mothborers, probably most of them, if not all, pyralids, occur all the way from Sierra Leone to Angola, and although their damage does not appear comparable to that of Diatraea in the American tropics, in commercial plantings, such as those at Catumbela, their ravages are something to be reckoned with. Lack of time and material prevented the rearing of adult specimens, but in Nigeria the sugar cane borer, according to F. D. Golding, the entomologist at Ibadan, is a species of Sesamia.

Spodoptera mauritia Boisd., known to Hawaii as the nutgrass armyworm, occurs from Sierra Leone eastward, at least into Nigeria. At Ibadan, a severe outbreak of this species occurred in May, the first in that district since 1921. Breeding in enormous numbers on grass, it migrated to corn used as an indicator crop in fertilizer tests, practically ruining it. Examination of over 100 larvae failed to reveal the presence of either external or internal parasites. In Sierra Leone Mr. Hargreaves records *mauritia* as attacking Sabal palm foliage.

Coleoptera:

A small rutelid beetle was taken on cane in Angola, but whether or not it actually attacks that plant is uncertain.

Anomala and related genera of beetles are wide-spread in West Africa, and their depredations on avocado and coffee, the favorite food plants of the adult, are occasionally severe. Scoliid wasps which might attack the grubs of this group are few in species and in numbers, and no larval parasites of the beetles are known to the entomologists with whom contact was made.

Following is a list of West African rutelid beetles compiled from records made available by Messrs. Hargreaves and Golding:

Species	Occurrence	Adult feeding plants
Adoretus mameratus Hope	Nigeria	
Adoretus hirtellus Cast.	Nigeria	Young cacao; Cola.
Adoretus similis Bend.	Sierra Leone	Cashew
Anomala chalcophora var. minor Ohs.	Sierra Leone	Avocado; *Cola nitida;* guava.
Anomala circumscriptus Hope	Nigeria	
Anomala denuda Arrow	Nigeria; Sierra Leone	Coffee; larvae in soil (about young cacao trees).
Anomala flaveola Burm.	Nigeria	
Anomala hygina Ohs.	Sierra Leone	
Anomala mixta Fab.	Nigeria	
Anomala olivacea Gyll.	Sierra Leone	
Anomala ruginosa Ohs.	Nigeria	
Anomala stigmaticollis Frm.	Sierra Leone	
Anomala sp.	Nigeria	
Chaetadoretus setipennis Ohs.	Sierra Leone	Avocado; guava; rose.
Popillia obliterata Gyll.	Sierra Leone	Rose
Popillia viridissima Blanch.	Sierra Leone	Bauhinia

In December, *Anomala denuda* was the common beetle at Njala, Sierra Leone, feeding on coffee foliage at night.

Fig. 1. Sugar factory and distillery, Angola (Portuguese West Africa).

Fig. 2. Irrigation dam, at mouth of gorge of Catumbela River, Angola.

Fig. 3. Main irrigation ditch, sugar plantation, Angola.

Fig. 4. Labor camp, sugar plantation, Angola.

Fig. 5. Nests of village weaver or palm bird on Raphia palm. Freetown, Sierra Leone, B. W. A.

Yams for Hawaiian Gardens—II

By E. L. Caum

Among the plants that might well be grown as accessory food crops in Hawaii, the yams take a prominent place. They are easy to propagate, yield heavily as a rule, are palatable and easy to prepare for the table.

The family of the yams, the *Dioscoreaceae*, is a large and complex group, widely distributed throughout the tropics and subtropics the world around. One species, which however is of very indifferent food value, is native to Hawaii. R. Knuth, who monographed the family in the monumental work "Das Pflanzenreich", recognized 655 species in the family, 614 of which belong to the genus Dioscorea, the true yams, the other 41 species being distributed among eight closely allied genera. If botanical and horticultural varieties are considered, the total number of kinds will in all probability exceed one thousand. Although many of these hundreds of species are of little or no economic significance, a number of them are food plants of importance in a greater or lesser degree. Several of them are sparingly grown in the Islands at the present time, and it seems as though more of them should be more widely planted.

In *The Hawaiian Planters' Record* for the second quarter of 1936 (pp. 171-182) was given a brief account of one of these species, the Spiny yam, *Dioscorea esculenta,* together with photographs of the tubers of other forms of Dioscorea. One form of *D. batatas,* the subject of the present sketch, is there illustrated (Fig. 13, p. 181). This plate is here reprinted as Fig. 1.

The Chinese yam or Chinese potato, *Dioscorea batatas,* is a native of China, Japan and Korea, and was described by Decaisne in the "Revue Horticole," Series IV, vol. 3 (1854), p. 243. It is a twining vine, 10 to 30 feet in length, with round or very slightly angular stems marked with purple, particularly on the exposed side. The leaves are opposite, obscurely three-lobed, the two lateral lobes rounded, the central one sharply pointed, 2½ to 4 inches long and somewhat less in width, 7 to 9 nerved, with a broad basal sinus (Fig. 2). There is a bright purple marking at the junction of the leaf blade and the short petiole. Usually, although not always, there is in each leaf axil a short recurved spine and very frequently one or two small potato-like aerial tubers (Fig. 3). The narrow spikes of white cinnamon-scented flowers arise singly or in clusters of two or three in the axils of the upper leaves. The odor of the flowers gives the plant the name "Cinnamon Vine" by which it is known on the mainland, where it is sometimes grown on arbors as an ornamental. The tubers are hardy and withstand the winters.

The tubers of the typical form of the Chinese yam are cylindrical, as much as four feet in length or even more, yellowish to gray-brown in color with white or yellowish inner skin and white flesh. They grow vertically, the upper end sometimes as much as three feet below the surface of the ground, and on that account difficult to dig. There are, however, a number of horticultural varieties. Makino, in "Nippon Shokubutsu Zukwan" (Illustrated Manual of Japanese Plants), states

that there are many named varieties of this yam grown in Japan, which differ from each other only in the size and shape of the tubers. One of these varieties, known to the Japanese as *tsukune,* bears tubers of two kinds. Some are flat and scalloped, while others are pestle- or flask-shaped, both forms being borne on the same vine. The upper left tuber in Fig. 4 is bifurcated, one half being flat, the other conic. Tubers of *tsukune* are occasionally imported from Japan, and small quantities of short tubers of the typical long cylindrical kind, called by the Japanese *nagaimo* (Fig. 1), are brought in from Japan and China. It is entirely probable that these yams are grown to some extent in Hawaii, although I have not found locally grown tubers in the markets. The species is listed in "Utilization and Composition of Oriental Vegetables in Hawaii" (Hawaii Agricultural Experiment Station Bulletin 60, December 1929, p. 55), but I believe the description and accompanying illustration are of another species of yam, probably a form of the widely distributed and extremely variable Winged yam, *Dioscorea alata.*

Of the various species and varieties of yams that are now growing in Hawaii or that may be grown as accessory food crops, the Chinese yam is probably the most difficult to harvest, due to the depth at which the tubers form. In making this statement I follow the literature. In the plants of *tsukune* grown in Manoa this past summer the tubers were just under the surface of the ground and were very easy to harvest, although the *nagaimo* tubers were much deeper. Opposed to the recorded difficulty in harvesting, however, are several advantages. The plant is easy to propagate: like all the yams, pieces of the tuber will grow. In the case of *tsukune* in particular, and this is probably the better variety of the two, the upper narrow neck may be used for planting material while the body of the tuber is used for food. As the latent buds at the upper end of the tuber germinate more rapidly than do those formed elsewhere, the amount of food material in the crop just harvested is reduced by the smallest possible amount in obtaining planting material for the next crop. Likewise the small aerial tubers may be planted, although they will not afford underground tubers of edible size in a single growing season. Fig. 5 shows the tiny pea-sized aerial "potatoes" and the subterranean tubers obtained in a single season from them. The second season will give tubers of usable size, probably about the size of those shown in Fig. 4, while after a third season they will be at their best. Although the plant has a short growing season—the Chinese yam will reach maturity and the vines die back in four to seven months as opposed to eight or nine months to a year for the Spiny and Winged yams—two or three of these growing periods are necessary to produce tubers of a size it is profitable to dig, depending on the size of the pieces planted. Tubers of *nagaimo,* cut up into pieces rather smaller than is best and planted in the Manoa Arboretum early in March, 1936, ripened off in seven months. The tubers were small, not more than half the size of those shown in Fig. 1. Tubers of *tsukune,* likewise cut too small, had grown their vines, flowered and died in less than four months. Some of this crop is shown in Fig. 4. In each case the crop was light and the tubers, although mostly of usable size, were small. Another growing season would put them at their best. These yams had been planted on a gentle slope in an abandoned cane field, and the soil was not prepared in any way. The cane and weeds were simply cut off and removed, and a shallow hole dug to receive the seed piece. Bamboo trellises were provided for

the vines. Had the land been plowed or even forked up sufficiently to remove the cane stubble, it is most probable that the crop would have been appreciably heavier. It would appear as though the best material for planting would be the smaller tubers, entire, rather than pieces of larger tubers, although this is pretty much a matter of choice.

The tubers are easy to prepare: I find in the literature nothing on the preparation of these vegetables other than a statement in the Hawaii Experiment Station bulletin previously mentioned, in which the instructions are: "Peel and wash. Slice in 2-inch squares one-fourth inch thick, and prepare as directed for arrowhead." The single recipe given for arrowhead is: "Wash and pare one-half pound arrowhead; . . . Slice one-half pound lean pork and mix with 1 teaspoon cornstarch, a little pepper, and one teaspoon soy sauce. Put in heated pot 1½ teaspoons peanut oil, one-half teaspoon salt, one slice ginger; add the pork and fry. Then add the arrowhead and stir vigorously for one minute. Add just enough water for gravy and cook over a slow fire until the vegetable is tender. Season and serve." These yams are used in other ways also. One method is to peel the tuber and grate it to a fine pulp which is eaten raw, seasoned with salt or soya and mixed with hot rice. Often the tubers are peeled and diced or cut into half-inch cubes and either steamed or cooked with soya and eaten as a side dish with meat or fish.

The Chinese yams, either the long cylindrical *nagaimo* or the smaller flat *tsukune,* are to the Chinese and Japanese what the Spiny yams are to the Filipinos.

Fig. 1. Tubers of *Dioscorea batatas,* variety *nagaimo.* These tubers, which were imported, are the most economical size.

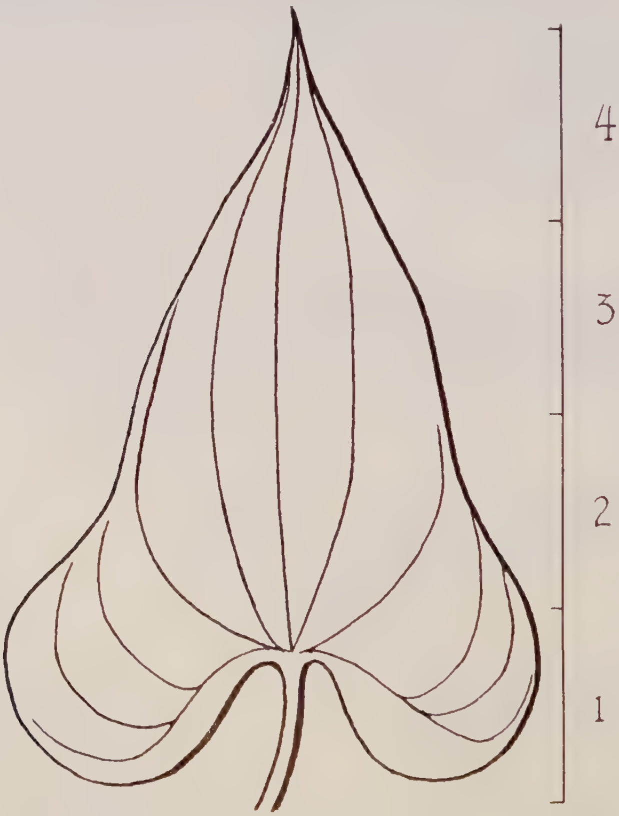


Fig. 2. A leaf of *Dioscorea batatas,* natural size.

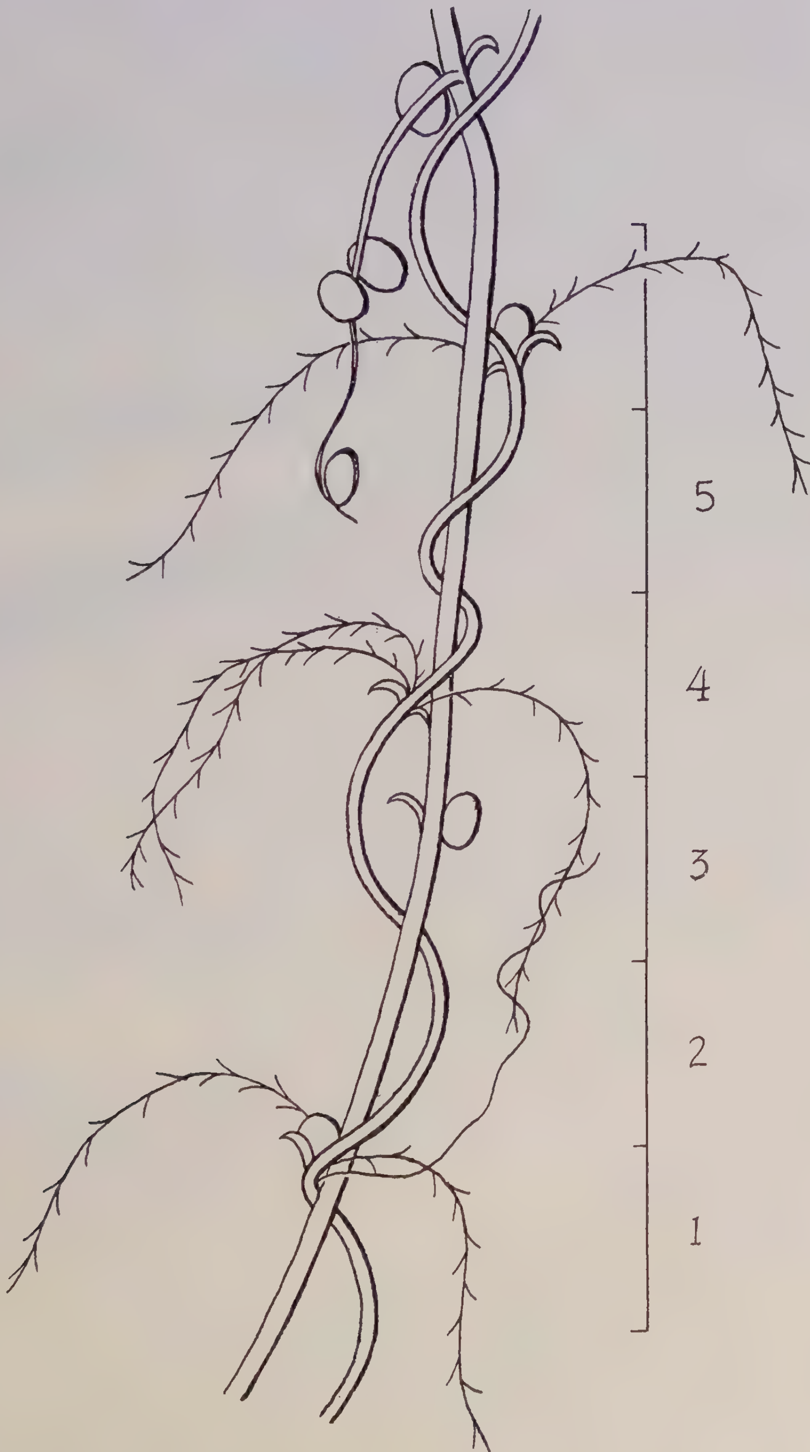


Fig. 3. A portion of the stem of *D. batatas,* (practically natural size), showing the axillary spines, the aerial tubers and the flower spikes.

Fig. 4. Small tubers of *D. batatas*, variety *tsukune*.

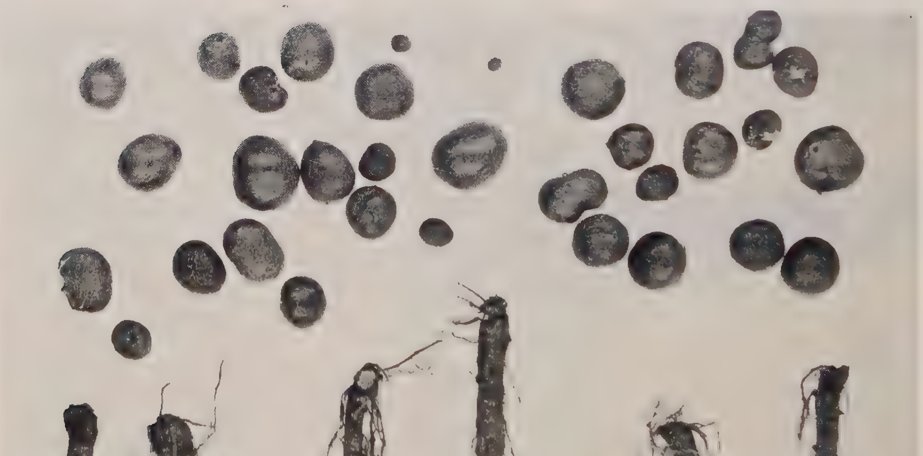


Fig. 5. Aerial tubers and first-season subterranean tubers of *D. batatas*.

Evaluation of Nitrogen in Molasses

By R. J. Borden

It is quite possible that the differences of opinion, which are found among plantation men regarding the value of molasses as a fertilizer for sugar cane, are the result of the differences in the conditions under which the effects of molasses on cane growth have been noted. And of such differences in conditions, we have special reference to differences in the available nitrogen supply of the soil, and to differences in the amounts of nitrogen fertilizer that were used along with the molasses applications that were made.

It is a well established fact that when a highly carbonaceous, quickly decomposable material like molasses, which has a wide carbon nitrogen ratio (estimated at about 50:1), is added to a fertile soil, the resulting soil microbial growth is so greatly stimulated that there is immediate competition between the soil organisms and the crop plants for the soluble nitrogen that is there. During this period of increased microbial activity which probably continues as long as the ratio of carbon to nitrogen in the soil remains somewhat greater than 10 to 1, the crop plant is apt to suffer from nitrogen deficiency, and a low-nitrogen soil will show this effect more rapidly and for a more extended period than a nitrogen-rich soil.

The results of another investigation that we planned in order to determine the crop-producing value of the nitrogen contained in molasses that had been incorporated with the soil, have substantiated our earlier study* of this issue, for again we find no increases in harvested dry weights which can be credited to the nitrogen in the molasses.

The soil used was an acid (pH 5.8), porous, sandy loam from our Manoa substation, which when tested by our standard Mitscherlich procedure, showed only 53 pounds of available nitrogen per acre-foot. Chemical analyses revealed the total nitrogen at .212 per cent, which indicates somewhat over 5,000 pounds per acre-foot. Available potash was definitely low, as also was the availability of phosphate to the crop grown. After a thorough mixing, the soil was divided into four portions for four series of treatments with respective checks:

- A—Nitrogen and molasses added together and soil thereafter fallowed in pots for 6 weeks before being planted.
- B—Same as A but fallowed for 4 months before planting.
- C—Molasses added alone and soil fallowed for 6 weeks before adding nitrogen and planting.
- D—Same as C but fallowed for 4 months.

During the so-called fallow period, these soils were kept moist and aerated in a warm greenhouse, and covered to prevent contamination; hence conditions for a satisfactory microbial activity were provided after the molasses had been added.

*Borden, R. J., 1935. Some Plant Food Values in Molasses and Filter Cake. *The Hawaiian Planters' Record*, 39:180-190.

Sufficient phosphate and potash to produce a maximum growth of the indicator crop (Sudan grass) were supplied when the soils were potted, and the following 12 differentials were provided for in each series:

Group	Treatment Nos.	Pounds per Acre of Nitrogen — From Molasses	From Fertilizer	Total N
Low nitrogen	1	0	57	57
	2	32	57	89
	3	65	57	122
	4	0	122	122
Medium nitrogen	5	0	142	142
	6	32	142	174
	7	65	142	207
	8	0	207	207
High nitrogen	9	0	227	227
	10	32	227	259
	11	65	227	292
	12	0	292	292

Thus in Series A and B we have what amounts to applications of molasses at the rate of 3 and 6 tons per acre to soils which had varying amounts of available nitrogen at the time this molasses was incorporated, while in Series C and D the available nitrogen content of the soil was low at the time the molasses was added and continued low during the entire fallow period following its application. There is thereby afforded a comparison of the effect of a difference in the length of the period allowed between the time of applying the molasses and of planting the crop, when both nitrogen-rich (Series A and B) and nitrogen-poor (Series C and D) soils are concerned.

Each series, potted in Mitscherlich pots, was planted with Sudan grass seed at the end of its respective period of fallow. This makes it a little difficult to make direct comparisons of the actual dry weights of individual treatments in Series A and C, with those in Series B and D, for since they were grown at slightly different times of the season, such weights perhaps reflect some differences in sunlight conditions which may have existed during the respective growth periods. Other than this, however, the data offer some interesting comparisons.

The first crops from each series were harvested at the age of 86 days. The plants were cut off at the surface of the soil, dried, and weighed. The stubble left in the pots was then "knifed" to a depth of several inches as the surface soil was being loosened for replanting; no stubble or root material was removed from any pot, and no drainage was lost. All pots were then refertilized with phosphate and potash only, and two weeks later they were replanted for a second crop. A month after the harvest of this second crop, a similar procedure of preparation, fertilizing and planting was followed for a third consecutive crop for Series A and C only.

These second and third croppings, without the further addition of nitrogen fertilizer, were for the purpose of determining whether that nitrogen which had been withdrawn and become tied up by the soil organisms would ultimately be released for the use of the crop being grown. It was apparent very soon after each successive crop was started that there was no available nitrogen present, and at the end of

the successive 90- and 60-day growth period, the dry matter secured clearly substantiated this fact. Hence, we were unable to recover for the use of our crop that nitrogen which had been taken up or dissipated by the soil organisms, even though a period of more than 9 months had elapsed since the microbial activity had been stimulated by the application of the molasses.

Since the dry weights secured from the second and third croppings are so small, and the differences between treatments in these crops are such as might easily be due to chance alone, a discussion of the results may well be confined to the data from the original or first crop harvested. The complete harvest data are offered in Tables I and II, and to facilitate study the more pertinent parts are also offered in graphic form in Fig. 1.

Reference to Fig. 1 quite clearly brings out the significant features of the results that were secured. These may be briefly enumerated and discussed, as follows:

1. The application of molasses to this soil was responsible for a definite loss in the weight of the crop harvested therefrom. In general this loss was greater when the molasses application had been at 6 tons per acre than at 3 tons per acre.

2. This depressing effect of molasses on the amount of dry matter produced was most pronounced when the amount of available nitrogen was low; as more nitrogen was furnished, the detrimental effect of the molasses became less pronounced: this was true (a) regardless of whether the soil was fallowed for 6 weeks or for 4 months, and (b) whether the different nitrogen levels were established at the time the molasses was applied at the beginning of the fallow, or at the end of the respective periods of fallow when the crop was planted.

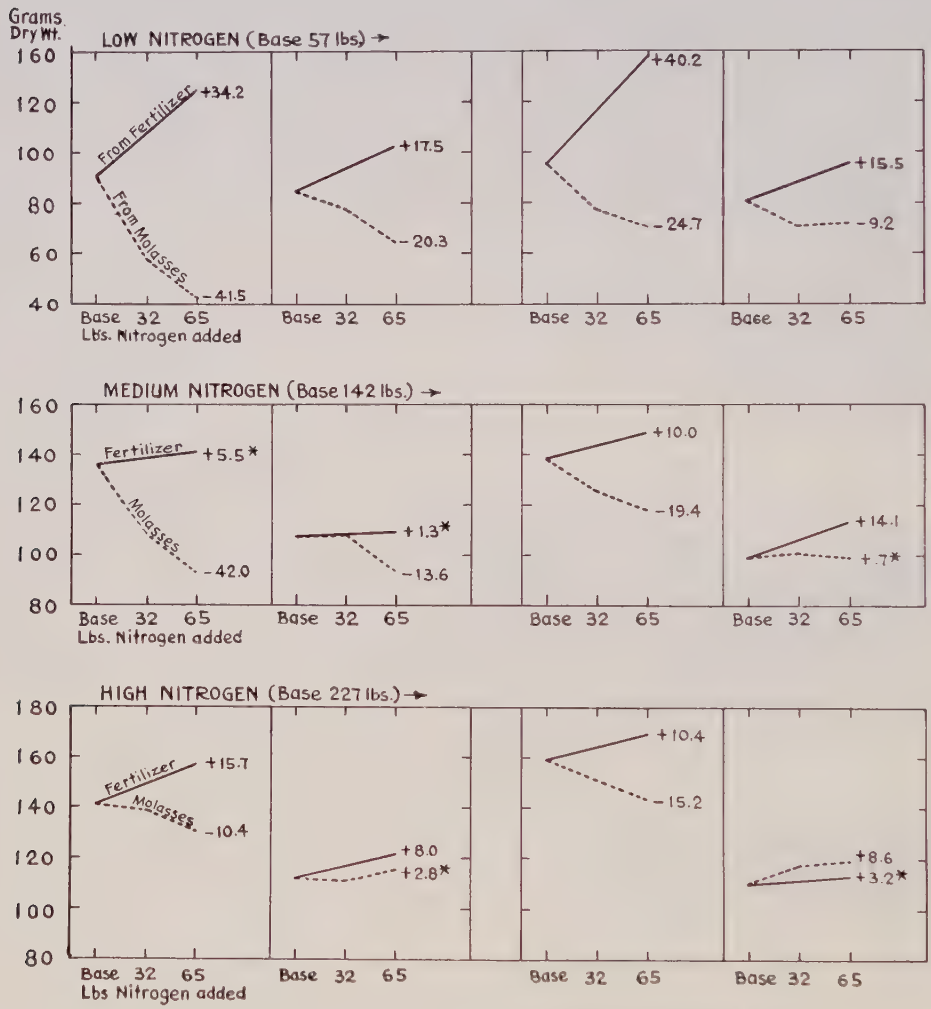
3. The losses in crop weights caused by the molasses applications were considerably greater when the crop was planted 6 weeks after molasses had been incorporated with the soil than when planting was delayed for 4 months. This was true, (a) regardless of whether the nitrogen was added at the same time as the molasses or 4 months later and, (b) with either low, medium, or high levels of available nitrogen.

4. Except in one case, we note that when a high nitrogen level was furnished the losses due to molasses were considerably reduced when the nitrogen was not applied with the molasses at the beginning, but was furnished at the end of the fallow period when the crop was planted.

5. Only in the case of a relatively high available nitrogen level, and when at least four months had elapsed between the application of molasses and the planting of the crop, did we find any indication at all that some of the nitrogen in the molasses may be released for the use of our crop, and this evidence is not entirely convincing. Thus we are led to the same conclusion that has been reached by many other research workers, i. e., that when the soil micro-organisms have been stimulated by supplying them with an easily decomposable carbonaceous material, there will most likely result an available nitrogen shortage for any crop plants growing on such soil. In addition, as yet, we have been unable to demonstrate that this nitrogen, which has been withdrawn by these micro-organisms during their greatly stimulated activity period, will be returned for use by the crops which follow when normal microbial conditions again prevail. Thus the initial nitrogen loss, which is clearly demonstrated, would appear to be a more or less permanent one, and we are therefore forced to admit doubt that the nitrogen content of molasses has any real value as a plant food which can be economically substituted, even in part, for a commercial nitrogen fertilizer.

Nitrogen and Molasses during Fallow — Series A (6 weeks fallow), Series B (4 months fallow)

Molasses only during Fallow — Series C (6 weeks fallow), Series D (4 months fallow)



* Amount of difference may likely be due to chance (less than 2 x SEd).

Fig. 1. Showing the total dry weights; also the amounts of gains and losses (as grams dry matter) for the addition to the base amounts indicated, of 65 pounds of nitrogen from fertilizer (solid line) and from molasses (broken line).

TABLE I

Nitrogen Status		Treatments: Amt. Molasses applied (tons per acre)	Treatments: Pounds Nitrogen per acre From Molasses	From Fertilizer	Total	Series A (fallowed 6 weeks) Avg. Dry Weight (grams ± SEd) First Crop	Second Crop	Third Crop	Total Three Crops	Series B (fallowed 4 months) Avg. Dry Weight (grams ± SEd) First Crop	Second Crop	Total Two Crops
Low	1	None	0	57	57	84.8±2.6	7.7±.1	4.2±.3	96.7	84.2±3.3	2.4±.2	86.6
	2	3 tons	32	57	89	57.7±1.6	8.5±.4	2.8±.2	69.0	78.3±2.5	2.9±.2	81.2
	3	6 tons	65	57	122	43.3±1.2	9.2±.2	3.5±.2	56.0	63.9±4.2	3.6±.3	67.5
	4	None	0	122	122	122.0±1.4	5.8±.3	4.1±.2	131.9	101.7±1.5	2.9±.0	104.6
Medium	1	None	0	142	142	135.7±2.0	6.2±.5	3.9±.3	145.8	107.1± .1	2.9±.1	110.0
	2	3 tons	32	142	174	108.5±1.0	8.7±.4	3.2±.2	120.4	107.9± .2	3.1±.1	111.0
	3	6 tons	65	142	207	93.7± .2	10.4±.2	2.9±.2	107.0	93.5±1.6	2.6±.0	97.1
	4	None	0	207	207	141.2±1.7	6.3±.0	3.5±.5	151.0	108.4±1.2	3.2±.1	111.6
High	1	None	0	227	227	141.1±1.7	6.0±.8	3.4±.1	150.5	112.5±1.4	3.3±.2	115.8
	2	3 tons	32	227	259	139.3±2.0	7.1±.1	3.3±.0	149.7	111.4± .0	2.8±.2	114.2
	3	6 tons	65	227	292	130.7± .8	9.0±.8	4.1±.1	143.8	115.3±2.9	3.3±.3	118.6
	4	None	0	292	292	156.8± .5	7.1±.2	3.0±.5	166.9	120.5±1.9	3.1±.1	123.6

In both Series A and B, the nitrogen variables were present throughout their respective fallow periods.

TABLE II

Nitrogen Status		Treatments: Amt. Molasses applied (tons per acre)	Pounds Nitrogen per acre: From Molasses	From Fertilizer	Total	Series C (fallowed 6 weeks) Avg. Dry Weight (grams ± SEd): First Crop	Second Crop	Third Crop	Total Three Crops	Series D (fallowed 4 months) Avg. Dry Weight (grams ± SEd): First Crop	Second Crop	Total Two Crops
Low	1	None	0	57	57	95.6± .6	6.9±2.3	3.2±.0	105.7	80.7±2.5	2.9±.2	83.6
	2	3 tons	32	57	89	77.4±3.7	8.5±1.9	4.6±.6	90.5	70.8±3.9	2.9±.0	72.7
	3	6 tons	65	57	122	70.9±1.5	10.8± .4	3.8±.1	85.5	71.5±2.8	2.9±.1	74.4
	4	None	0	122	122	135.8± .3	7.5± .2	3.6±.1	146.9	96.2±5.4	2.6±.1	98.8
Medium	1	None	0	142	142	137.7± .9	7.8± .8	3.3±.2	148.8	98.6±5.7	3.2±.6	101.8
	2	3 tons	32	142	174	126.1±1.3	9.8± .8	3.4±.6	139.3	101.1±2.2	3.0±.3	104.1
	3	6 tons	65	142	207	118.3± .4	10.1± .4	3.8±.2	132.2	99.3±1.3	3.2±.4	102.5
	4	None	0	207	207	147.7±1.1	6.8± .2	3.3±.4	157.8	112.7±2.1	3.3±.4	116.0
High	1	None	0	227	227	159.0± .4	7.3± .4	2.9±.3	169.2	110.6±1.6	3.0±.2	113.6
	2	3 tons	32	227	259	150.8±1.4	8.5± .4	3.3±.2	162.6	117.5±5.3	2.9±.1	120.4
	3	6 tons	65	227	292	143.8±4.9	8.1± .4	3.0±.1	154.9	119.2±2.1	3.6±.1	122.8
	4	None	0	292	292	169.4±1.1	6.6± .6	3.5±.4	179.5	113.8±3.9	3.3±.1	117.1

In both Series C and D, the nitrogen variables were not added until the end of the respective fallow periods.

Summary of Laboratory Studies of Anomala, 1933-1935

By R. H. Van Zwaluwenburg

Anomala Coefficient

Almost ever since the recognition of *Anomala orientalis* as a cane pest on certain areas in the Pearl Harbor district of Oahu, it has been obvious that economic loss is heaviest in the light, residual, red soils of the upland fields, and that box canyon fields of alluvial soil, even when surrounded by heavily infested fields, never suffer noticeably from the grubs. Serious outbreaks of Anomala, renewed in 1930, after several years of apparent control by natural agencies, made it important to learn what essential differences exist between soils heavily infested and those apparently immune. The answer was believed to lie in some physical difference between the soils themselves, and, as this was a problem beyond the scope of unaided entomological investigation, the assistance of H. A. Wadsworth, professor of soil physics at the University of Hawaii, was enlisted early in 1933.

After a scrutiny of results secured from a measurement of the physical properties of soils coming from areas of known Anomala history, a relationship was proposed which, although crude, proved to be a valuable index of a soil's susceptibility to Anomala infestation:

$$\frac{\textit{Ignition loss}}{\textit{Moisture equivalent}}$$

The resulting quotient is termed the "Anomala coefficient". It is *of value only in soils having a negligible organic content,* as is the case with all the lateritic and alluvial soils throughout the area involved.

Previous soil investigation in Hawaii indicates that upland soils (among which are the Anomala areas) are relatively rich in colloidal iron and aluminum, and poor in colloidal silica and alumino-silicates. A characteristic of soils high in iron and aluminum colloids is a high ignition loss.* With only a low moisture equivalent reading, and no other data, it is impossible to know whether a soil is low in colloidal material or whether there is present a larger percentage of colloids of low water-holding capacity. But if there is the added information that the ignition loss is high, it is safe to assume that the soil contains a large amount of colloidal material, and a relatively large amount of some intensively weathered form of iron or aluminum. Such weathering adds water in such a form that it remains in the soil when dried at 105° C. but is completely given off at the higher temperature (900° C.) to which ignition-loss samples are subjected. Hence the Anomala coefficient is a

---

* *Ignition loss* is determined as follows: The soil sample is oven-dried at 105 degrees Centigrade to get the constant weight; it is then ignited for 30 minutes at 900 degrees Centigrade. The resulting loss in weight is then divided by the original oven-dried weight to obtain the ignition loss.

Moisture equivalent is determined by the following method: The sample is placed in a small brass box provided with screen and filter paper bottom. The soil is saturated and subjected to a centrifugal force equivalent to 1000 times the force of gravity. The percentage of moisture remaining in the soil after 30 minutes in the centrifuge is the moisture equivalent.

measure of colloidal iron and aluminum content; a high content of these materials is a striking characteristic of soils susceptible to severe Anomala damage in Hawaii.

The application of this work to field observations results in the following soil classification:

Class 1. Soils not susceptible of commercial damage from Anomala. Anomala coefficients less than 0.45.

Class 2. Soils susceptible of moderate commercial damage. Anomala coefficients from 0.45 to 0.65.

Class 3. Soils susceptible of great commercial damage. Anomala coefficients more than 0.65.

Low Anomala coefficients are associated with soils that rapidly dry into hard clods or lumps to an appreciable depth. High Anomala coefficients are associated with soils that dry into light, fluffy masses, free from clods and cracks; the subsoil protected from drying acts as a suitable medium for Anomala development for long periods, even in the absence of rainfall or irrigation.

The value of the Anomala coefficient lies principally in the assurance which it gives most of the cane plantations in the Territory that Anomala will probably never assume first-rate proportions as a pest in their areas, even should it pass the boundaries of its present range. On Oahu it is fairly certain that Anomala already occupies all of the area favorable to its existence in destructive numbers. On Maui and on Kauai there are limited cane areas in which, if the concept is sound, the beetle could increase to destructive numbers; this information prompts us to watch these areas with especial care. The extreme dependence of Anomala upon favorable moisture conditions makes it easy to understand why it has never been found in unirrigated land devoted to pineapples.

Soil Moisture

Study of contrasting soil types reveals that the crux of the difference between them is the effect upon Anomala eggs of the rapidity with which the unfavorable soil loses free moisture, as contrasted with its retention by the favorable soil. The two types may even show identical percentages of moisture content, but the unfavorable soil holds more of this water so tightly that it is unavailable to the eggs. Absorption of moisture from the surrounding medium is essential to the development and hatching of the egg. Unfavorable soil loses its available moisture remarkably rapidly, and Anomala eggs placed in mudballs of such soil collapsed within 24 hours and died, presumably due to the withdrawal of water from the egg by the soil. In mudballs of favorable soil the originally added moisture was sufficient for normal development and hatching. So long as moisture is maintained at the point necessary for incubation, it makes no difference if the soil is of the favorable or unfavorable type; the same percentage of hatching results in approximately the same time.

It was originally thought that the tendency of unfavorable soil to harden and lump was the essential deterrent to Anomala development, due to the difficulty which grubs must meet in working through such soil to find food. This may be

partially true, especially with newly hatched grubs, but mature grubs can make their way through even dry, lumpy soil, with remarkable ease. In unfavorable soil, kept adequately moist at all times, newly hatched grubs travel through the sticky mass with little difficulty.

Effect of Humidity Differences Upon Incubation of Eggs

Apparently Anomala eggs gain moisture for their development from the air in the soil. If the relative humidity of the soil air is high, such supplies of moisture are easily available. If the humidity is relatively low, egg development is hindered and under extreme conditions a marked collapse of the eggs occurs. Of striking significance is the narrow range of relative humidities which can be tolerated by eggs of this species.

The degree of moisture depletion of the soil air necessary to kill Anomala eggs was found to be extremely slight. Having determined that eggs hatch normally under favorable moisture conditions, even in the absence of soil, Prof. Wadsworth and the writer set up series of sealed chambers having various ranges of relative humidity controlled by different solutions of sulphuric acid. Reductions in relative humidity were found to affect not only the percentage of eggs hatching, but to influence also the length of incubation period. The following figures (at an average mean room temperature of about 78° F.) are characteristic of the results obtained:

Per cent Relative Humidity	Incubation Period	Percentage of Hatch
100	14.8 days	100
99.5	16.0	95.0
98.7	17.4	95.0
97.9	17.8	30.0
97.1	18.0	5.0
96.3	....	0

The critical point for the eggs in the above experiment lay between 98.7 and 97.9 per cent relative humidity. The soil atmosphere in soil moistened to the maximum field capacity, is 100 per cent; at the wilting point it is about 99 per cent.* In another experiment in which the soil was moistened somewhat above the maximum field capacity (but not flooded) hatching was delayed; the percentage of hatch was nearly that of the check (100 per cent relative humidity).

Life-History Studies

Egg stage:

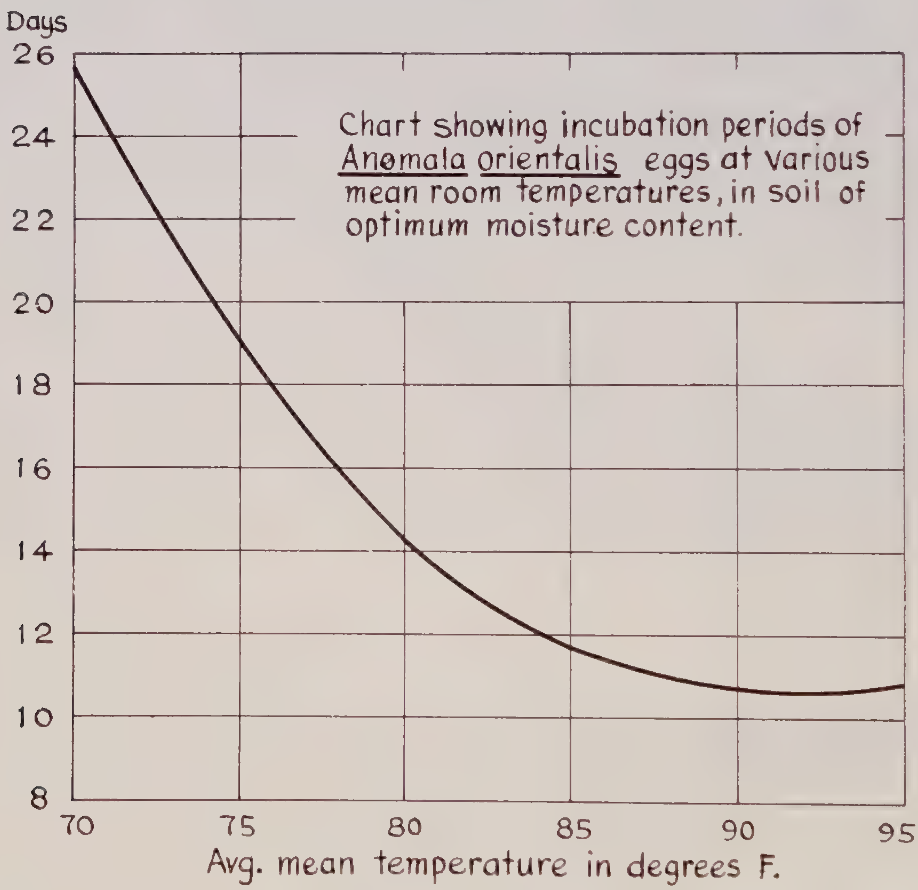
As is to be expected, there is a definite inverse correlation between temperature and length of incubation. The accompanying illustration shows the average incubation period of Anomala eggs in soil of approximately the optimum moisture content, for various average mean temperature (Fahrenheit).†

---

* Recent work by Schofield (International Congress of Soil Science, 1935, Vol. 2, pp. 37-48) suggests that the permanent wilting per cent for some soils is associated with a relative humidity of 98.9 per cent. (H. A. Wadsworth.)

† We are indebted to the local laboratory of the U. S. Bureau of Entomology and Plant Quarantine for the use of constant-temperature cabinets in these and other experiments.

In the field Anomala eggs are normally laid within the first foot of soil, and it is not probable that they ever meet the upper extremes of average temperature shown on the chart. Average soil temperatures at a depth of 12 inches, in fields in the upper and middle Anomala belts, may be expected to show ranges, depending upon the season, comparable to the following, calculated on the basis of work by Das (*The Hawaiian Planters' Record,* 38; p. 79, 1934) and Weather Bureau figures (Upper Hoaeae, elevation 705 ft., 1925-1934):



Soil covered by cane crop..................	61.5 to 69.0 degrees F.
Bare soil................................	69.5 to 76.9 degrees F.

In dry soils the figures would be somewhat higher, and there would be a greater daily fluctuation than in soils kept moist by irrigation.

Repeated unsuccessful attempts to hatch Anomala eggs in a constant temperature of 100° F., prompted the following experiment to determine how long an exposure to this temperature is necessary to kill all eggs. Ten vials of 14 newly laid eggs each were put in a constant temperature cabinet, and at 24-hour intervals one

vial was withdrawn and placed at room temperature (which averaged about 78° F.). Hatching was as follows:

Hours exposure to 100° F. before removal to room temperature	Average incubation period	Percentage hatching
24	14.6 days	50.0
48	17.1	23.0
72	17.5	30.7
96	18.0	15.3
120	18.5	14.2
144	....	0
168	....	0
192	....	0
216	....	0
240	....	0

No eggs hatched after exposure to a constant 100 degree temperature for 144 hours or longer.

Hagan, working at Wahiawa, elevation 900 feet (*Soil Science,* 36, pp. 83-95, 1933), found that in uncovered soil at the ¼-inch depth, summer temperatures frequently rose to above 104 degrees for two hours or more, and that at 3 inches they occasionally rose to between 100.4 and 104 for two hours or longer. Accordingly, Anomala eggs in soil of optimum moisture content were exposed in a constant temperature cabinet for two hours daily to temperature of 104 degrees, followed by removal to room temperature. These eggs took slightly longer to hatch than did a check lot held at room temperature, but the percentage of hatching was about the same. This indicates that even if eggs are laid in bare soil within 3 inches of the surface they can survive the high diurnal temperatures encountered there, provided adequate moisture is present.

Pupal stage:

As with eggs, there is an inverse correlation between temperature and the duration of the pupal stage of Anomala. This is shown by the following figures, obtained in the quarantine laboratory from pupae kept on the surface of moist soil:

	Males		Females		Average mean
Pupating in	No.	Average	No.	Average	temperature
January	9	11.4 days	12	11.1 days	75.2 F.
February	56	11.2	50	10.8	75.7
March	75	10.5	112	10.1	76.1
April	14	10.6	14	10.2	76.0
May	35	9.3	64	9.1	79.6
June	3	9.1	16	8.7	80.6

Throughout the beetle order, so far as the writer knows, females take longer in the pupal stage than males; hence the reverse condition, demonstrated above and shown by critical examination to be statistically significant, is of interest. Possibly female adults remain for a time in the soil where they have pupated, before issuing above ground.

Miscellaneous:

The following miscellaneous data were obtained from 77 reared Anomala females kept in the laboratory with males always present, and fed on flower blossoms or apple:

	Average	Minimum	Maximum
Preoviposition period	7.1 days	4.5 days	18.5 days
Actual days of egg laying	8.3 days	2 days	14 days
Total egg laying period	11.4 days	2 days	23 days
Eggs laid per female	32.1 eggs	10 eggs	67 eggs

Females surviving from 1 to 10 days after last egg laying: 43.

Longevity of adult beetles:

The following data were obtained from mated, reared adults confined in jars of moist soil, and fed regularly; included are 77 laying females and 7 that died without laying any eggs:

	No. beetles	Average life	Minimum	Maximum
Females	84	17.3 days	1.5 days	30 days
Males	88	18.0 days	2 days	48 days

In addition, 3 unmated females lived 23.5, 25.5 and 29.5 days respectively, laying a total of 26 eggs, none of which hatched.

Summary of life history:

From the foregoing data the following approximate life cycle has been estimated for beetles hatching from eggs laid during the spring months:

Egg stage	14- 25 days
Grub stage	120-130 days
Pupal stage	9- 11 days
Preoviposition period	5- 18 days
Total	148-184 days

There is a wide individual variation in the length of the grub stage particularly; some grubs take over twice the indicated time to complete their development.

The above estimates agree fairly well with rearing experiments conducted in the open at Waipio with the assistance of J. S. Rosa. In an effort to get seasonal data on life history under simulated field conditions, 5 tubs of soil planted to cane were started monthly and seeded with 50 eggs each; these were kept under favorable moisture conditions by additions of water. From 35 tubs (5 per month from December to June) with 50 eggs each, only 9 Anomala were reared to the adult stage. While a low survival, the results are comparable to those obtained by other

workers (e.g., Bianchi, *The Hawaiian Planters' Record,* 39: 234-255, 1935). The 9 beetles required the following lengths of time to attain the adult stage:

From eggs laid in:	Days from egg to adult:
December	160 - 163
January	140 - 143
"	152 - 155
"	181 - 184
February	166 - 170
"	169 - 172
March	165 - 168
"	165 - 168
June	165 - 175

The average time from egg to adult stage was 164.5 days; individual variation ranged from 140 to 184 days. Incidentally this experiment proves that if the moisture factor is kept favorable, Anomala can develop successfully in even an unfavorable soil, for due to a misunderstanding the work was conducted with soil having an Anomala coefficient of 0.44.

Miscellaneous Observations

Ratio of sexes:

Of a total of 520 beetles reared in the laboratory from grubs collected in the field, 309 were females, and 211 males. This is roughly in the ratio of 3 females to 2 males.

Effect of submergence on egg-hatching:

Fifty newly laid eggs were placed in soil, and one inch of water allowed to stand on the surface for 10 days. At the end of that time the eggs were removed to favorably moist soil, and eventually 38 per cent hatched normally; a check lot showed 97 per cent hatch.

Fertility of eggs:

Seven hundred twelve eggs from field-collected female beetles, kept in jars of moist soil in close confinement with males, showed 98 per cent fertility. Under the circumstances females could hardly escape mating, but the experiment is perhaps comparable to conditions in heavily infested fields. Eggs from unmated females, as previously noted, do not hatch.

Occurrence of black-phase beetles:

Anomala adults which are blackish instead of the more usual strawcolor, are common in the field. Laboratory study indicates that there is no important differ-

ence between the black and the light phases with regard to fertility and longevity. The relative abundance of the two phases, compiled from local data is as follows:

		Black-phase beetles	
Field-collected	Total beetles	No.	Percentage of total
O. H. Swezey (1916-1925)..........	2253	593	26.3
F. A. Bianchi (1930-1932)..........	689	176	25.5
Total......................	2942	769	26.2
Laboratory-bred			
January-March	314	69	
April	28	5	
May	99	27	
June	19	3	
Total......................	460	114	24.7
Total of both field-collected and laboratory-bred beetles	3402	873	25.6

Arsenic concentrations lethal to newly hatched grubs:

Laboratory experiments with extremely thorough mixtures of white arsenic and soil, prepared by the Chemistry department, placing Anomala eggs in the soil and leaving the hatching grubs exposed to the poison for 14 days after hatching, show that concentrations of 250 parts or more per million (by weight) of white arsenic, causes a very high mortality of young grubs. Assuming a weight of from 2.5 to 3 million pounds per acre-foot for typical Anomala soils, a reasonably effective control of newly hatched grubs is to be expected from applications of from 625 to 750 pounds of white arsenic, mixed in the top foot of soil.

The Synthesis of Sucrose by Excised Blades of Sugar Cane

By Constance E. Hartt

In a study of the fluctuations of sugars in the leaf blades of the sugar cane plant during the day and the night (3), the author stated that it is impossible in the present state of our knowledge to give a decisive answer to the question whether cane sugar or the simple sugars arise first in the process of photosynthesis. If the simple sugars arise first, then there must be present in the leaf of the sugar cane plant a mechanism for the conversion of simple sugars to cane sugar. The purpose of this paper is to present evidence indicating that the leaf blade of the sugar cane plant can manufacture cane sugar when supplied with the simple sugars—glucose and fructose.

Methods

The plants used in this investigation were of the variety H 109, planted in pots of good soil and kept in a sunny part of the grounds of the Experiment Station. The plants, which had been ratooned on November 30, 1935, were given uniform fertilization and irrigation under the direction of Dr. A. J. Mangelsdorf. The same plants were used in a study of water and cane ripening. For the investigation reported herein, the leaves only were taken. Counting the leaf with the highest visible dewlap as leaf number one, leaves number two and three were used in each test. The leaves were cut between eight and nine o'clock in the morning and were placed immediately in the required solutions. The studies now reported deal with samples of leaves taken between July 20 and September 17, 1936.

All of the tests were conducted in the constant-temperature room, at room temperature, in absolute darkness.

Analyses were made of moisture and sugars using the methods cited in a former paper (2). Cane sugar was determined by inversion by a solution of Wallerstein invertase scales according to the method of Hassid (4).

Results

Experiment 1. Feeding with glucose and/or fructose results in an increase in sucrose:

The blades were cut at 8:20 a. m., July 20, 1936, and were placed in flasks of distilled water in the constant-temperature room at 8:35. After 24 hours, the blades were removed from the water, their ends wiped dry, and they were then placed in the sugar solutions for 24 hours in the dark, each blade in 300 cc. solu-

tion. The ends of the blades were rinsed with distilled water, wiped, and the leaves were then sampled. The following series were taken:

1: Untreated
2: Water 24 hours
3: Water 24 hours, and then 10 per cent glucose 24 hours
4: Water 24 hours, then 5 per cent glucose plus 5 per cent fructose 24 hours
5: Water 24 hours, then 10 per cent fructose 24 hours

The results of the determinations of moisture and sugars are presented in Table I, which shows that keeping excised blades in darkness in water for 24 hours resulted in an increase in percentage of moisture. The changes in percentages of the sugars were within the limits of experimental error.

The percentage of simple sugars in the blades was more than doubled by supplying them with glucose or fructose or both. The differences in sugar content between Series 3, 4, and 5, are probably explained by the fact that in this first test the sugar solutions were not prepared quantitatively.

TABLE I

Moisture and Sugar Percentages in Blades in Experiment 1; Moisture Percentages Expressed Upon the Wet-Weight Basis; Sugar Percentages Upon the Dry-Weight Basis

Series	Moisture	Simple Sugars	Cane Sugar	Total Sugars
1: Untreated	65.94±0.067	0.996±0.040	2.376±0.115	3.497±0.161
2: Water	69.84±0.205	1.083±0.019	2.399±0.003	3.609±0.016
3: Water, glucose	65.24±0.105	2.631±0.014	7.892±0.173	10.939±0.196
4: Water, fructose + glucose	65.95±0.100	3.061±0.005	9.272±0.005	12.822±0.004
5: Water, fructose	65.87	3.351±0.008	9.018±0.057	12.844±0.069

The percentage of cane sugar in the blades was nearly trebled by supplying them with glucose or fructose or both.

Before concluding from this experiment that the blades absorbed glucose and fructose and synthesized cane sugar therefrom, it is necessary to consider other possible explanations of these results. Fortunately we are dealing with cut blades and know that no changes can be due to translocation from other organs. The changes must be due either to absorption from the solution supplied, or to rearrangements within the leaf, the study of which was the object of the second experiment.

Experiment 2. A complete nutrient solution did not increase the percentages of sugars:

The suggestion may be made that during the second 24-hour period in Experiment 1 there may have been a breakdown of starch or other polysaccharides resulting in higher percentages of sugars, due to a higher osmotic concentration or withdrawal of water. To determine this point, an experiment was conducted in which a balanced nutrient solution of osmotic concentration approximately equal to that of the sugar solutions used in Experiment 1 was employed.

The solution was prepared as follows. Since a 10 per cent solution of glucose equals 100 grams per liter, and a gram molecular solution of glucose equals 180.15 grams per liter, the solution used in Experiment 1 was approximately ½ gram molecular, and had an osmotic pressure of about 11.2 atmospheres, not being ionized. A balanced nutrient solution of approximately 11.2 atmospheres pressure was therefore prepared using potassium phosphate, calcium nitrate, and magnesium sulphate.

The blades were cut on August 12 and placed in the dark for 24 hours. Seven blades were used in each series for the determination of sugars, and each blade received 100 cc. of water or solution.

The following series were distinguished:

1: Untreated
2: In water 24 hours
3: In solution 24 hours

After 24 hours in the dark, the blades of Series 2 were normal in appearance, while those of Series 3 were somewhat dried, rolled, a little stiff in texture, were less green, and had developed reddish streaks throughout almost their entire length.

The percentages of moisture and sugars are presented in Table II, which

TABLE II

Moisture and Sugar Percentages in Blades in Experiment 2; Moisture Percentages Expressed Upon the Wet-Weight Basis; Sugar Percentages Upon the Dry-Weight Basis

Series	Moisture	Simple Sugars	Cane Sugar	Total Sugars
1: Untreated	69.09±0.114	1.074±0.008	2.214±0.004	3.404±0.012
2: Water	67.72±0.229	0.734±0.019	1.607±0.017	2.426±0.002
3: Solution	64.53±0.119	1.032±0.028	1.625±0.020	2.743±0.007

shows that the blades kept for 24 hours in the concentrated solution lost water. Their content of simple sugars remained the same as that of the untreated blades, which was a little larger than that of Series 2 (in water). The cane sugar content decreased in the dark, being the same as that of the series in water. Thus although the concentration of the external solution was sufficient to cause a decrease in water content in the blades, there is no evidence of an increase in cane sugar resulting therefrom.

Therefore, unless the changes in the blades obtained in Experiment 1 were due to some internal factor other than loss of water or change in osmotic concentration, the evidence indicates that excised blades of the sugar cane plant can manufacture cane sugar in the dark, when supplied with glucose or fructose or both.

Experiment 3. Effect of concentration of glucose:

The blades were cut on August 19 and were immediately placed in the requisite solution, 100 cc. of water or solution for each blade. Fourteen blades were used

in each series, half of which were kept for the determination of invertase, to be reported later. The series were as follows:

1: Untreated
2: 24 hours in water
3: 24 hours in 1 per cent glucose
4: 24 hours in 2 per cent glucose
5: 24 hours in 5 per cent glucose
6: 24 hours in 10 per cent glucose
7: 24 hours in 25 per cent glucose

With the exception of Series 1, the blades remained in their respective solutions for 24 hours, after which time the blades of Series 2-6 were in uniformly good condition, while the blades of Series 7 were rolled.

The results of the determinations of moisture and sugars are recorded in Tables III and IV and Fig. 1, which show that the greater the percentage of glucose supplied, the greater the percentage of sugars within the leaf.

TABLE III

Moisture and Sugar Percentages in Blades in Experiment 3; Moisture Percentages Expressed Upon the Wet-Weight Basis; Sugar Percentages Upon the Dry-Weight Basis

Series	Moisture	Simple Sugars	Cane Sugar	Total Sugars
1: Untreated	65.91±0.067	1.064±0.027	2.475±0.039	3.670±0.015
2: Water	68.62±0.148	1.042±0.003	2.208±0.011	3.367±0.008
3: 1 per cent glucose	68.24±0.339	1.236±0.008	2.576±0.042	3.948±0.036
4: 2 per cent glucose	70.02±0.453	1.362±0.019	3.536±0.054	5.084±0.076
5: 5 per cent glucose	66.34±0.124	1.459±0.012	5.204±0.013	6.937±0.001
6: 10 per cent glucose	64.62±0.315	2.874±0.038	8.473±0.117	11.794±0.162
7: 25 per cent glucose	59.83±0.391	8.565±0.016	9.593±0.086	18.663±0.074

If the percentages of sugars in Series 2 are subtracted from those in Series 3-7, the percentages gained by the leaves from the sugar supplied are obtained. Now if the percentage increase in cane sugar is divided by the percentage increase in total sugars, the result is the percentage of glucose absorbed which is converted into cane sugar. The higher the percentage the greater the efficiency of the synthesis or manufacture of cane sugar, and this figure is hereafter called the "synthetic efficiency." The results of these calculations are presented in Table IV, which shows that increasing the concentration of glucose supplied from one to 10 per cent increased the gain in cane sugar from 0.3 per cent to 6 per cent, but increasing the concentration of glucose supplied from 10 to 25 per cent increased the gain in cane sugar from 6 to 7 per cent only. Increasing the concentration of glucose supplied from one to 10 per cent increased the gain in simple sugars from 0.2 per cent to 1.8 per cent, whereas increasing the concentration of glucose supplied from 10 to 25 per cent increased the gain in simple sugars from 1.8 per cent to 7.5 per cent. The same point is illustrated graphically in Fig. 1, in which the slope of the curve for cane sugar is greater between one and 10 per cent glucose supplied than between 10 and 25 per cent, and the slope of the curve for simple sugars is less between one and 5 per cent than between 5 and 25 per cent.

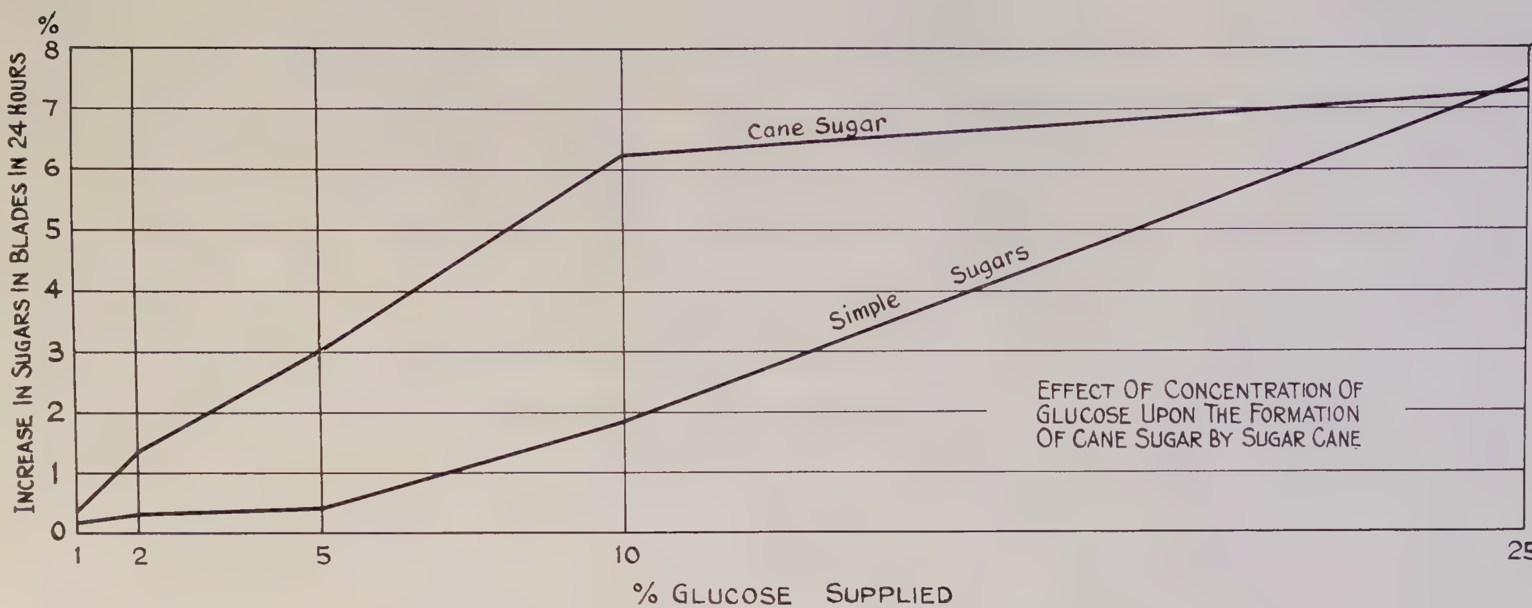

EFFECT OF CONCENTRATION OF GLUCOSE UPON THE FORMATION OF CANE SUGAR BY SUGAR CANE
Cane Sugar
Simple Sugars
INCREASE IN SUGARS IN BLADES IN 24 HOURS
%
8
7
6
5
4
3
2
1
0
1
2
5
10
25
% GLUCOSE SUPPLIED

Fig. 1.

TABLE IV

Gains in Sugars, and Synthetic Efficiency, of Blades in Experiment 3; Percentages Expressed Upon the Dry-Weight Basis

Series	Simple Sugars	Cane Sugar	Total Sugars	Synthetic Efficiency
3: 1 per cent glucose	0.194	0.368	0.581	63.33
4: 2 per cent glucose	0.320	1.328	1.717	77.34
5: 5 per cent glucose	0.417	2.996	3.570	83.92
6: 10 per cent glucose	1.832	6.265	8.427	74.34
7: 25 per cent glucose	7.523	7.385	15.296	48.28

The greater amount of gain in cane sugar was obtained at the lower concentration of glucose supplied, whereas the greater amount of gain in simple sugars was obtained at the higher concentrations of glucose supplied. When there was only a little glucose supplied, most of it was used in the formation of cane sugar; but when a greater amount of glucose was supplied, although more cane sugar was formed, there was a larger residue of simple sugars in the blade not used in the formation of cane sugar. Perhaps more of the glucose at the higher concentrations would have been converted into cane sugar if given sufficient time.

When the solution of glucose supplied was 25 per cent, the gain in simple sugars approximately equalled the gain in cane sugar. In other words, 48 per cent of the simple sugar absorbed was converted into cane sugar, or the synthetic efficiency was 48 per cent. Table IV shows that the synthetic efficiency varied with the concentration of glucose supplied, being greatest in a 5 per cent solution, in which 83 per cent of the sugar absorbed was converted into cane sugar. This figure illustrates the strength of the mechanism of sucrose synthesis in sugar cane. In the subsequent experiments only 5 per cent solutions of glucose or fructose were used, since the synthetic efficiency was greatest at that concentration.

Experiment 4. Effect of molasses:

Coincident with Experiment 3, a test was conducted to determine whether or not molasses could be used instead of glucose. Blades were kept in a 10 per cent solution of molasses for 24 hours, after which time the following percentages were obtained: moisture, 59.58 per cent; simple sugars, 1.559 per cent; cane sugar, 2.396 per cent; total sugars, 4.082 per cent. When these results are compared with those presented in Table III, the blades supplied with molasses are found to have had a gain in simple sugars comparable to that gained by the blades supplied with a 5 per cent solution of glucose, but no significant gain in cane sugar. The 10 per cent solution of molasses was found to be 2.58 per cent reducing substance. Therefore there was something in the molasses which inhibited the conversion of glucose into cane sugar. This experiment will be repeated using several concentrations of molasses.

Experiment 5. The effect of time upon the formation of sucrose from glucose:

The blades were placed in flasks at 8:30 a. m. September 15, with 100 cc. of a 5 per cent solution of glucose for each blade. There were 16 blades in each series, half of which were used for the determination of sugars reported in this paper and half for the determination of invertase to be reported later. The series were as follows:

1: Untreated (8:30 a. m.)
2: In dark 1 hour (9:30 a. m.)
3: In dark 2 hours (10:30 a. m.)
4: In dark 3 hours (11:30 a. m.)
5: In dark 5 hours (1:30 p. m.)
6: In dark 7 hours (3:30 p. m.)
7: In dark 11 hours (7:30 p. m.)
8: In dark 24 hours (8:30 a. m.)

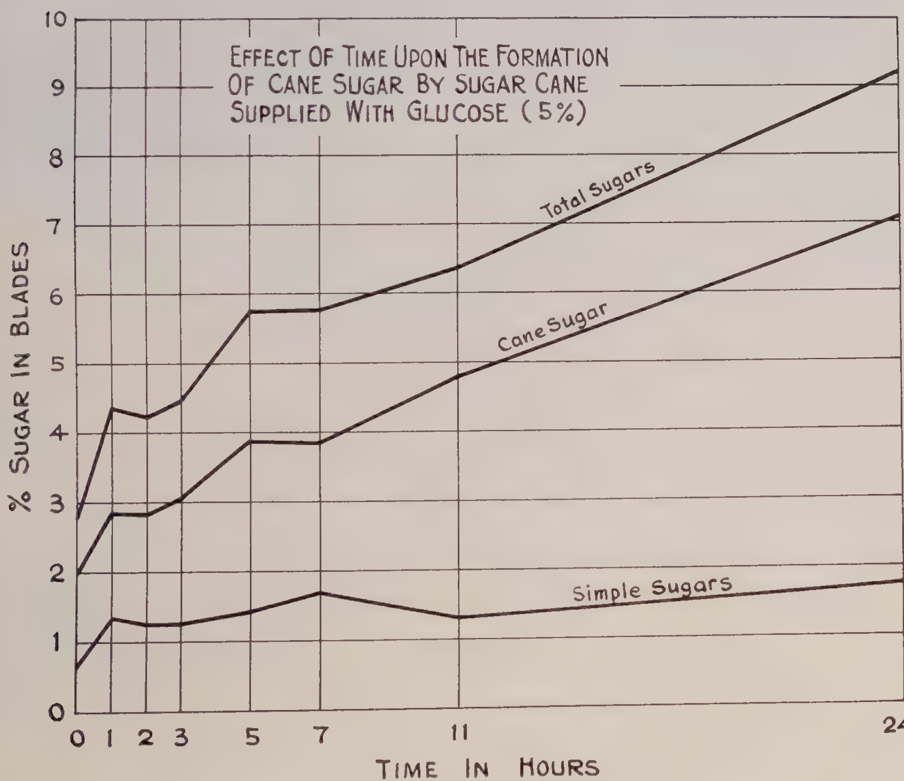


Fig. 2.

The results of the determinations of moisture and sugars are recorded in Table V and Fig. 2, which show that the greatest increase in percentage of simple sugars occurred during the first hour, after which time the percentage of simple sugars in the blades remained fairly uniform for 24 hours. The percentage of cane sugar also increased during the first hour, followed by an hour or so of no increase, and thereafter for 24 hours a fairly steady increase in cane sugar occurred.

TABLE V

Moisture and Sugar Percentages in Blades in Experiment 5; Moisture Percentages Expressed Upon the Wet-Weight Basis; Sugar Percentages Upon the Dry-Weight Basis

Series	Moisture	Simple Sugars	Cane Sugar	Total Sugars
1: Untreated	64.54±0.153	0.649±0.006	1.986±0.007	2.739±0.013
2: 1 hour	68.84±0.105	1.353±0.005	2.855±0.016	4.358±0.022
3: 2 hours	67.34±0.477	1.239±0.012	2.841±0.034	4.230±0.048
4: 3 hours	67.97±0.014	1.254±0.033	3.038±0.030	4.453±0.001
5: 5 hours	67.38±0.153	1.425±0.042	3.894±0.013	5.524±0.029
6: 7 hours	66.58	1.674±0.020	3.861±0.008	5.738±0.011
7: 11 hours	66.33±0.548	1.314±0.007	4.795±0.045	6.360±0.055
8: 24 hours	66.78±0.372	1.769±0.018	7.060±0.001	9.202±0.019

Experiment 6. The effect of time upon the formation of sucrose from fructose:

The blades were placed in the flasks containing their respective solutions at 8:30 a. m., September 17. The experiment was identical with Experiment 5, except that the sugar supplied was fructose instead of glucose. The fructose used in Series 2-8 was a 5 per cent solution prepared from the rootstalk of the ti plant by Dr. U. K. Das, to whom the author expresses grateful appreciation. The sugar used in Series 9 was chemically pure fructose supplied by the Pfanstiehl Chemical Company.

The results of the determinations of moisture and sugars, which are presented in Table VI and Fig. 3, are similar to those obtained in Experiment 5, using glucose. The blades supplied with fructose increased in percentage of simple sugars during the first hour, after which time their percentages of simple sugars remained

TABLE VI

Moisture and Sugar Percentages in Blades in Experiment 6; Moisture Percentages Expressed Upon the Wet-Weight Basis; Sugar Percentages Upon the Dry-Weight Basis

Series	Moisture	Simple Sugars	Cane Sugar	Total Sugars
1: Untreated	68.05±0.076	0.819±0.019	2.178±0.058	3.112±0.042
2: 1 hour	67.18±0.009	1.241±0.044	2.604±0.011	3.983±0.056
3: 2 hours	66.45±0.157	1.284±0.025	2.591±0.018	4.012±0.044
4: 3 hours	67.40±0.181	1.272±0.023	2.616±0.032	4.026±0.057
5: 5 hours	66.66±0.038	1.211±0.030	2.992±0.041	4.361±0.074
6: 7 hours	67.01±0.343	1.327±0.018	3.629±0.005	5.148±0.024
7: 11 hours	68.59±0.057	1.586±0.021	5.527±0.005	7.404±0.027
8: 24 hours	68.21	1.618±0.003	7.122±0.015	9.115±0.013
9: 24 hours (c. p. fructose)......	65.44±0.157	1.420±0.030	6.867±0.024	8.649±0.005

fairly uniform for 24 hours. The percentage of cane sugar also increased during the first hour, after which there was no gain for two hours, followed by a steady gain throughout the remainder of the 24-hour period.

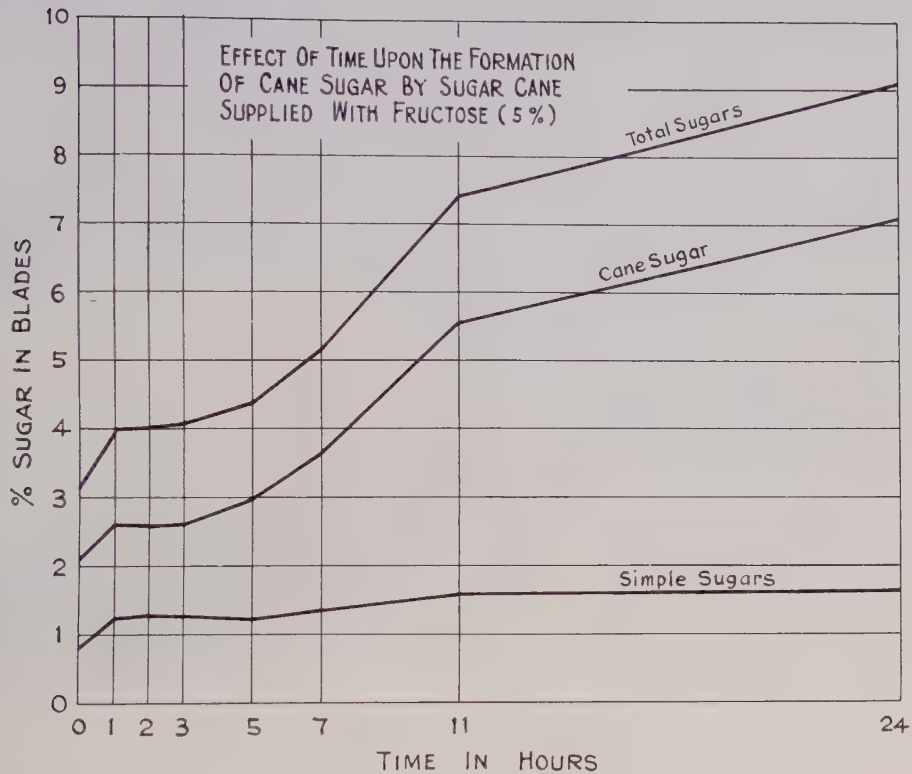


Fig. 3.

The results of Experiment 6 therefore confirm those of Experiment 5. Whichever simple sugar is supplied, whether glucose or fructose, it is the cane sugar which varies the most in concentration in the leaf.

Comparison of Series 8 and 9 (Table VI) shows that the fructose prepared from the rootstalk of the ti plant and the chemically pure fructose prepared by the Pfanstiehl Chemical Company were used equally well in the absorption of simple sugars and formation of cane sugar by the sugar cane plant.

Experiment 7. The formation of cane sugar does not require chlorophyll:

One albino stalk and one green stalk taken from the same plant of the variety POJ 2878 were cut early in the morning of August 6, 1936, at the Oahu Sugar Company, placed in a tin, and brought to the Enzyme Laboratory by J. P. Martin. The albino stalk bore only three leaves. The upper and lower leaves were placed in the dark, and the middle leaf was used as the untreated series. The series were as follows:

1: Albino untreated
2: Green untreated
3: Albino in sugar
4: Green in sugar

Series 3 and 4 received 100 cc. of a 10 per cent solution of glucose per blade, and were placed in the dark at 11:30 a.m. August 6 where they remained for 24 hours.

The results of the determinations of moisture and sugars are recorded in Table VII, which shows that the albino leaf increased in cane sugar from 0.576 per cent to 7.955 per cent or a difference of 7.379 per cent, while the green leaf increased in cane sugar from 2.500 per cent to 9.741 per cent or a difference of 7.241 per cent. Therefore, when supplied with glucose an albino leaf can make cane sugar as well as a green leaf.

TABLE VII

Moisture and Sugar Percentages in Blades in Experiment 7; Moisture Percentages Expressed Upon the Wet-Weight Basis; Sugar Percentages Upon the Dry-Weight Basis

Series	Moisture	Simple Sugars	Cane Sugar	Total Sugars
Untreated				
1: Albino	79.87	2.089	0.576	2.695
2: Green	74.45±0.734	1.559±0.009	2.500±0.004	4.191±0.004
In Sugar				
3: Albino	75.03±0.548	4.735±0.025	7.955±0.166	13.109±0.200
4: Green	74.82±0.210	5.510±0.053	9.741±0.085	15.764±0.036

Discussion

The manufacture of cane sugar from simple sugars, the role of the enzyme invertase, and the question of which sugar is formed first in photosynthesis are closely related problems, for, if cane sugar is the primary sugar in photosynthesis, then the role of invertase may be only hydrolytic and it is possible that all of the cane sugar present in the sugar cane plant is formed without using glucose and fructose; whereas, if the simple sugars are formed first, there must be some mechanism for their conversion into cane sugar, and that mechanism might be the enzyme invertase.

Definite evidence that the leaf of the sugar cane plant possesses a mechanism for the conversion of glucose and fructose into cane sugar has been presented in Tables I, III, V, VI, and VII and in Figs. 1-3. The fact that the sugar cane leaf can manufacture cane sugar from simple sugar when artificially supplied with glucose and fructose does not necessarily prove that that is the natural method of formation of sucrose, but is strong presumptive evidence.

The fact that neither light nor chlorophyll is necessary for the formation of sucrose shows that cane sugar can be made by a process other than photosynthesis but does not prove that cane sugar is always made by a process other than photosynthesis. This manufacture of cane sugar takes place against a gradient, i.e. there is always less simple sugar than cane sugar in the blades, according to Tables I, III, V, VI, and Table VII with the exception of the "albino-untreated."

Therefore, the argument that leaves cannot manufacture cane sugar from the simple sugars in nature because leaves contain less simple sugar than cane sugar, is not founded upon fact.

The formation of cane sugar from simple sugars in blades containing less simple sugars than cane sugar is explainable by the fact that there was a high head of glucose in the external solution, comparable to the hypothesized formation of simple sugars in the process of photosynthesis.

The mechanism for producing cane sugar from simple sugars was strong enough to handle nearly all of the glucose absorbed when supplied at the lower concentrations, according to Table III and Fig. 1. This ability may be the same whether the simple sugar is supplied artificially as in these experiments or naturally as in photosynthesis. This statement is in agreement with the viewpoint that the reason simple sugars in the blades of the sugar cane plant fluctuate by day less than cane sugar does is because the simple sugars are formed first in photosynthesis and are only transitory in occurrence while cane sugar is a storage form.

The curves presented in Figs. 2 and 3 closely resemble those obtained in the studies of the fluctuations of sugars in the blades of the sugar cane plant during the day and the night (3). In both studies the curves for simple sugars are flatter than those for cane sugar, indicating considerably less fluctuation in simple sugar content than in cane sugar content. The difference between this experiment and photosynthesis is that here we know we have a simple sugar first, whereas in photosynthesis that is a question. The fact that similar types of curves are formed both in photosynthesis and in artificial feeding in the dark suggests that in both processes glucose is used up so rapidly that there is not enough left to accumulate, a theory already proposed by several physiologists for photosynthesis.

The results presented in this paper are in accord with the viewpoint that the simple sugars are formed first in photosynthesis and are then converted into cane sugar. The formation of cane sugar does not require light, as shown by these experiments. The manufacture of cane sugar in nature stops at nightfall, not because light is required for its immediate formation, but because without light the production of simple sugars by photosynthesis ceases. When a supply of simple sugars is furnished without photosynthesis, the formation of cane sugar proceeds readily in the dark.

Cane sugar is, of course, a double sugar yielding upon digestion equal parts of glucose and fructose. The question arises as to how the blade can form cane sugar when supplied with glucose or fructose alone. Since this formation actually occurs, according to the results presented in this paper, the conclusion seems inevitable that the blade of the sugar cane plant possesses a mechanism for the interconversion of glucose and fructose. We are not concerned here with the chemistry of this mechanism, which has been studied in other plants and in vitro by numerous investigators, but merely with the fact that it does take place.

When supplied with glucose, the blades reached 7.060 per cent cane sugar, as shown in Table V; when supplied with fructose, the blades reached 7.122 per cent cane sugar, as shown in Table VI. Therefore the ease of forming glucose from fructose equals the ease of forming fructose from glucose. This fact may be of fundamental importance in the sugar cane plant, as it may be responsible for the chief storage carbohydrate being cane sugar rather than starch as in the corn plant, or inulin as in the ti plant.

The necessity for the formation of glucose from fructose and vice versa, in the blades supplied with only one simple sugar, may explain the lag in the formation of cane sugar after the first hour, illustrated in Figs. 2 and 3. In the experiment in which glucose alone was supplied, perhaps the little fructose already present within the blade was used during the first hour, and during the second hour enough fructose may have been formed from the glucose absorbed to permit further formation of cane sugar. If this explanation is correct, there should be no such lag in the manufacture of cane sugar when both glucose and fructose are supplied in equal amounts, a point to be determined in another experiment.

The fructose immediately formed by the digestion of cane sugar is unstable, changing very quickly into a more stable form. The cane sugar molecule requires the unstable, highly reactive form of fructose and its absence hinders or prevents the synthesis of cane sugar in vitro and is often presented as evidence that the action of the enzyme invertase cannot be reversible. The results herein presented show that a sugar hydrolyzable by invertase is formed by the blades of the sugar cane plant when supplied with either glucose or fructose. Evidently the blades of the sugar cane plant are not only able to convert glucose to fructose, but also to convert the stable form of fructose into the unstable form of the sugar necessary for the manufacture of sucrose. The possible importance of phosphorus in the formation of glucose-phosphate as an intermediate step in these processes will be considered in another experiment.

The results reported herein are in agreement with those obtained by Virtanen and Nordlund (7), with red clover and wheat, both in demonstrating a formation of cane sugar from simple sugars and in indicating a mutual interconversion of glucose and fructose. Our results are also in accord with the further work of Nurmia (née Norlund) (5, 6), using wheat, oats, clover, and horse bean. Recalculation of the data presented by Nurmia (5) shows that the leaves of the horse bean, when placed in a 10 per cent solution of glucose for 24 hours, had a synthetic efficiency of 38 per cent, and when placed in a 10 per cent solution of fructose for 24 hours, the leaves had a synthetic efficiency of 48 per cent. Since the blades of the sugar cane plant in a 10 per cent solution of glucose for 24 hours possessed a synthetic efficiency of 74 per cent, according to Table IV, we may conclude that the sugar cane leaf possesses a much more efficient mechanism for the manufacture of cane sugar than is found in the leaf of the horse bean. This difference should be expected, since the natural storage food is cane sugar in the sugar cane plant but not in the horse bean, in which the natural storage foods are protein, fat, and starch.

Coelingh and Koningsberger (1) found that the leaf of sugar cane of the variety POJ 2878 can form starch in the dark from a sugar solution, using maltose, cane sugar, glucose and fructose. The formation of starch, and the use of sugars other than glucose and fructose, have not yet been studied in this investigation.

Now that it has been determined that the blade of the sugar cane plant possesses a highly efficient mechanism for the production of cane sugar from the simple sugars, glucose and fructose, the next step is to determine if possible whether or not this mechanism is the enzyme invertase. This point is now being studied and the results will be reported later. Other experiments not included in this paper have shown that neither sulphur nor magnesium is needed for the conversion of the

simple sugars to cane sugar. The effects of external conditions upon the efficiency of synthesis should be determined, also the question as to what other organs of the sugar cane plant are able to conduct the synthesis.

Summary

1. The leaf blade of the sugar cane plant can manufacture cane sugar when supplied with the simple sugars, glucose and fructose.

2. This process takes place in the dark.

3. It does not require chlorophyll.

4. There is always a higher percentage of cane sugar than of simple sugars in the blades, no matter what the concentration of glucose supplied, within the limits of 1-25 per cent.

5. The synthesis is most efficient when the blades are supplied with a 5 per cent solution of glucose, in which 83 per cent of the sugar absorbed is converted into cane sugar in 24 hours.

6. Since the synthesis takes place when the blades are supplied with glucose or fructose alone, and since cane sugar contains both, a transformation from glucose to fructose and from fructose to glucose occurs in the blades of the sugar cane plant.

7. The interconversion of glucose and fructose occurs equally well whichever sugar is supplied.

8. The cane sugar fluctuates more widely than the simple sugars in the blades supplied with glucose or fructose.

9. The results herein reported are thus in agreement with the viewpoint that the simple sugars are formed first in photosynthesis and are then converted into cane sugar.

Acknowledgment

The writer is indebted to Dr. Mangelsdorf for having the plants irrigated and fertilized; to Mr. Martin for the albino cane material, and to Dr. Das for supplying the fructose.

Grateful appreciation is expressed in particular to Ada Forbes for her valuable cooperation throughout the study.

The writer desires especially to thank Dr. H. L. Lyon for his inspiration and encouragement in facilitating this research.

Literature Cited

1. Coelingh, W. M., and Koningsberger, V. J., 1932. Suikervorming en rijpingsverloop bij suikerriet. 2de Bijdrage. Over zetmeelvorming in de bladeren van suikerriet. Archief voor de Suikerind. in Ned. Ind. 40, Deel 3:1325-1339.

2. Hartt, C. E., 1934. Water and cane ripening. The Hawaian Planters' Record 38:193-206.

3. ————————, 1935. The fluctuations of sugars in the leaf blades of the sugar cane plant during the day and the night. The Hawaiian Planters' Record. 39:298-326.

4. Hassid, W. Z., 1936. Determination of reducing sugars and sucrose in plant materials. Ind. Eng. Chem. Anal. Ed. 8:138-140.

5. Nurmia, M. (née Nordlund), 1935. Interconvertibility of glucose and fructose in plant tissue. Nature 135:345.

6. ———, 1935. Transformation of sugars in plant. Ann. Acad. Sci. Fennicae 44A, No. 8, 105 pp. (Chem. Abs. 30:1418. 1936.)

7. Virtanen, A. I., and Nordlund, M., 1934. Synthesis of sucrose in plant tissue. Biochem. Journ. 28:1729-1732.

The Availability of the Principal Nutrients in a Soil During the Crop-Growth Period

By Ralph J. Borden

The general practice, when sampling cane field soils for the analysis and determination of their available nutrient status so that fertilizer recommendations can be more intelligently made, is to collect the soil sample either before the plant crop is fertilized, or in the interim between harvest and the first fertilization of the succeeding ratoon. Hence, by far the greater part of the analytical data that we have previously recorded is concerned with a measure of the fertility status that exists in the soil at the beginning (or the end) of the cropping period.

The desire to know more about the availability of the three principal plant foods in the soil throughout the progress of the growth of a crop of cane, led to plans for securing a continuous record of these nutrients by both chemical and biological analyses of soil samples taken from the active root zone twice a month during the entire growth period.

Through the cooperation of Waialua Agricultural Company an apparently uniform area in Field Helemano 5A was chosen, where a ratoon crop of H 109 was being started on November 16, 1934. The area was divided into 2 sections, each comprising three adjacent watercourse plots occupying approximately one-half acre; the 2 sections were separated by a single watercourse plot. Within each of these 2 sections (A and B) 12 sampling points were definitely established. The soil that was submitted from each section for analysis at each date of sampling was a composite sample made up by taking 2 borings with a 4-inch soil auger to a depth of 12 inches, in the sides of the cane line adjoining each of the 12 sampling points, thus there are 24 borings for each composite soil sample. The auger holes were filled up and marked with a wire pin and successive soil samples were always taken in the cane line within 12 inches of the previous borings.

The first samples were collected on November 17, 1934 and thereafter the areas were sampled on or about the 15th and 30th of each month to and including August 30, 1936.

In order to get a general idea of the natural fertility status in this area without having to contend with a complication that would be introduced if commercial fertilizer were applied, the crop was allowed to go without any fertilization until March 12, 1935. Hence we were able to collect the first 8 samples from cane rows which had not been fertilized.

Adequate and similar amounts of irrigation and weed control were given to both sections. Commercial fertilizer applications were carefully made by hand to the cane rows in each section, according to the following plan:

Sec.	3/12 1935 ℔ K_2O	3/20 1935 ℔ N	4/9 1935 ℔ P_2O_5	5/15 1935 ℔ N	6/15 1935 ℔ N	7/15 1935 ℔ N	9/16 1935 ℔ N	3/16 1936 ℔ N	Totals N	Totals P_2O_5	Totals K_2O
A	50	40	200	40	0	40	40	40	200*	200	50
B	50	90	200	0	90	0	0	60	240	200	50

*Due to the heavy cane growth and trash, a final application of 40 pounds of nitrogen scheduled for the "A" section in April 1936 was omitted.

Chemical analyses of these periodic soil samples have been made in our Chemistry department. These have included determinations of pH, phosphoric acid, potash, ammoniacal and nitrate nitrogen by the rapid chemical methods (hereafter referred to as R.C.M.), and of the percentage of total and of water soluble nitrogen by the Kjeldahl method. The phosphate fixation index was also secured.

Biological analyses of these same soil samples were made in our Mitcherlich department. These included determinations of the indicated amounts of available nitrogen, phosphoric acid and potash.

The results of the many analyses have furnished us with an array of figures which are offered in Table II. All percentage figures received from the analyst have been calculated to pounds per acre-foot of soil (2,500,000 pounds) and are tabulated as such to facilitate comparisons with the Mitscherlich results.

In presenting the data, we have averaged the 2 samples that were taken each month, and have used this average monthly figure in building up the bar-graphs which follow, in order to show the general trends without confusing the reader by presenting all of the variations that were found in the successive samples. This procedure should not, however, let us lose sight of the fact that we may find quite sizeable variations in the analytical results from soil samples, even when such samples have been reliably taken from almost the same spots in the field only some 2 weeks apart. Undoubtedly a soil sampling error contributes to a large part of this variation, but it is not altogether improbable that it is also influenced by conditions that are the result of differences between the uptake of nutrients by the growing plants and the total available nutrient supply, natural and added, in the soil. A general idea of the range of these variations that existed is shown as pounds per acre-foot of soil as follows:

	Section A	Section B
Range of available nitrogen:		
By R.C.M. analysis................	15 to 98 ℔	13 to 125 ℔
By Mitscherlich test...............	41 to 131 ℔	42 to 253 ℔
Range of available phosphoric acid:		
By R.C.M. analysis................	70 to 550 ℔	30 to 400 ℔
By Mitscherlich test...............	44 to 298 ℔	33 to 196 ℔
Range of available potash:		
By R.C.M analysis................	75 to 275 ℔	75 to 300 ℔
By Mitscherlich test..............	281 to 844 ℔	367 to 873 ℔

In Figs. 1 and 2, we show the monthly variation of available nitrogen, determined by the Mitscherlich test and R.C.M. respectively, as it occurred in both Sections A and B. During the first 4 months, before any fertilizer was applied, there was but little change in the status of available nitrogen. With the application of ammonium sulphate in March 1935, there was an immediate increase of nitrogen found in the soil, especially from Section B, which had received the heavier application. This was chiefly ammonia nitrogen (from the ammonium sulphate). The manner and speed with which it was nitrified and removed from the soil is indicated in Fig. 3—within a period of 6 weeks it had entirely disappeared. The larger nitrogen fertilizer applications at later dates were similarly effective in increasing the available nitrogen supply of the soil, but for a very short period only.

The low point for nitrogen in the soil was reached in January and February, 1936, and was still apparent when the spring dressing was applied in March.

There was an excellent correlation between the Mitscherlich results and those secured by the rapid chemical methods (R.C.M.), although the Mitscherlich results were in general about 3 times larger. The only significant difference between the average nitrogen status of the 2 sections was in the amount of total nitrogen; this was significantly greater in Section A. The more interesting of the nitrogen data are summarized in Table I.

Fig. 1

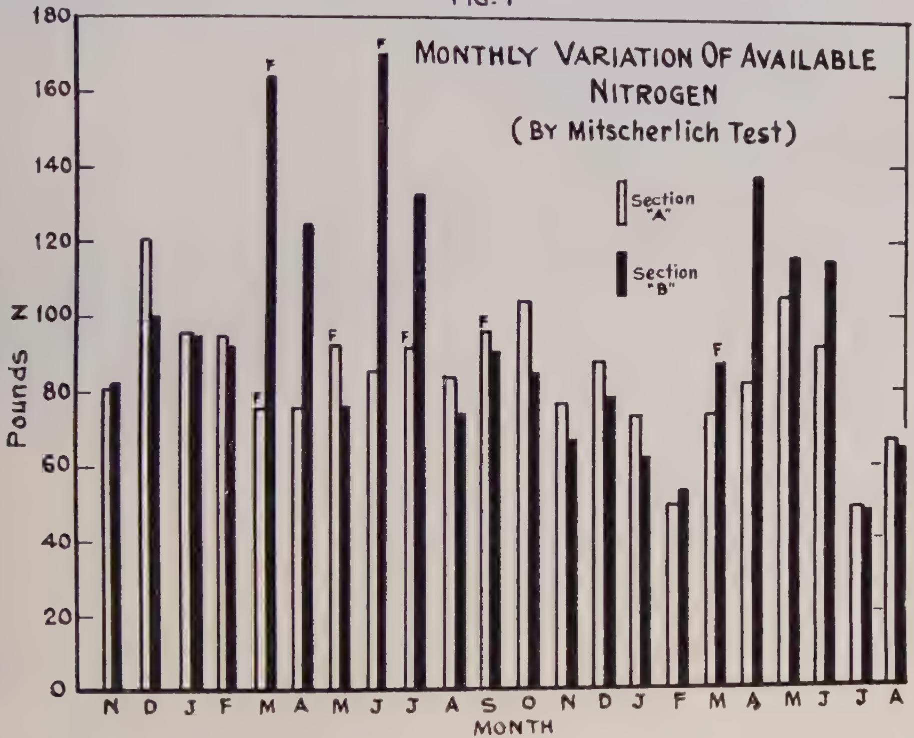
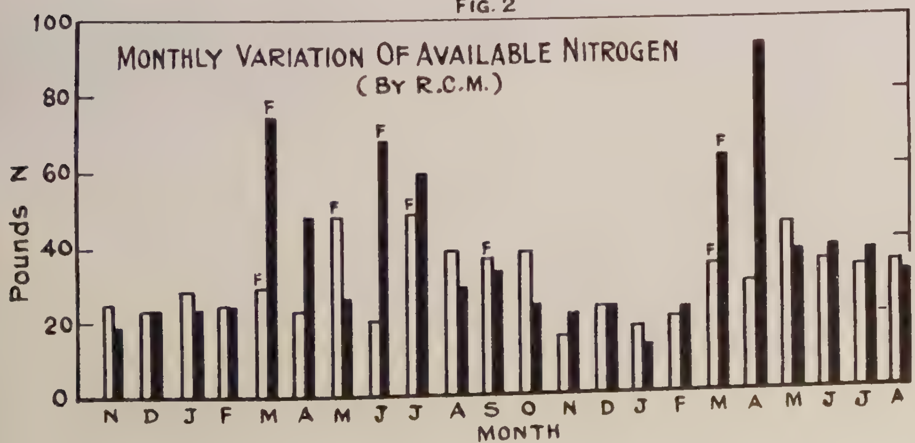


Fig. 2



F = Fertilized with Nitrogen

FIG. 3

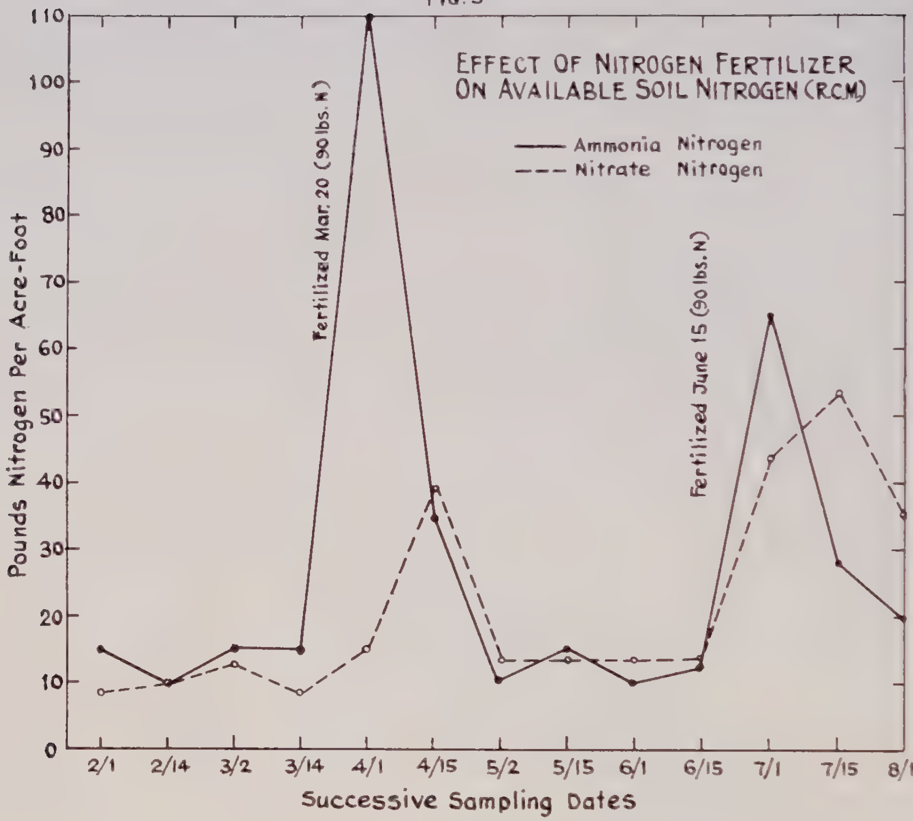


TABLE I

Summary of Pertinent Nitrogen Data

	Section A*	Section B
1. Average lb nitrogen per acre-foot, during 22 months:		
By R.C.M.	34	42‡
By Kjeldahl (water sol.)	35	41†
By Mitscherlich	97	119†
By Kjeldahl (total)	5777	5637‡
2. Percentage of total nitrogen:		
Available by Mitscherlich	1.68%	2.11%
Water soluble (Kjeldahl)	.60	.73
Water soluble (R.C.M.)	.59	.75
3. Correlation coefficients:		
Between Mitscherlich and (R.C.M.)	$+.90 \pm .020$	$+.88 \pm .023$
Between R.C.M. and Water sol. (Kjeldahl)	$+.53 \pm .074$	$+.77 \pm .041$
4. Correlation between Section A and Section B:		
For R.C.M. nitrogen	$+.79 \pm .039$	

* Section A—43 samples Section B—44 samples
† Difference not significant
‡ Difference significant

The monthly variation in available potash is shown in Fig. 4. The steady increase in available potash that is apparent at the start of the crop before the potash fertilizer was applied, may indicate that the withdrawal by the growing crop at this age and time was slower than the rate at which the soil potash was being made available; hence it accumulated. The influence of the potash fertilization is shown in the March-April analyses. The drop in potash that is noticed in the first summer is probably due to the heavy demands made on potash by the crop which was then in its "boom" stage. The reason for a slight increase in August-September-October is speculative.

The relatively low amount of available potash in the soil during the second season is thought to be due to the heavy drain that has by that time been made upon it by the crop. Since this condition may be the result of a luxury consumption of potash, and at any rate since it is generally believed that sufficient potash has already been taken up by the cane plant and can be translocated and re-utilized within the plant system until the crop is harvested, such low available potash in the soil at this time may be without any real practical significance.

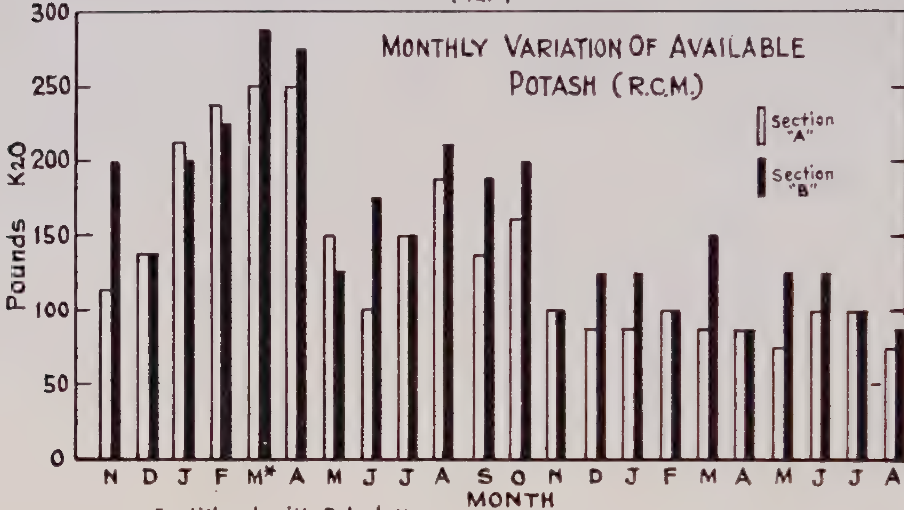
The similarity of the available potash status in the 2 sections (A and B) is indicated by their coefficient of correlation: $+.80 \pm .037$. The similarity between the Mitscherlich results and the results by R.C.M. for potash is not as consistent as the nitrogen comparisons were, but the relationship is nevertheless a definitely positive one, as will be indicated by these coefficients of correlation: $+.65 \pm .059$ for Section "A," and $+.50 \pm .076$ for Section "B."

In Fig. 5, the monthly picture of the supply of available phosphoric acid in the soil of a field which has been fertilized with phosphates is full of interest for the student of soil sampling for fertility studies. An even better picture is obtained from an inspection of the individual items in Table II in the column headed "P_2O_5-R.C.M." Although the soil sample that was analyzed was a composite of 24 auger borings taken from the cane row, and at each successive sampling date the new borings were each made within 12 inches of the previous bore, the variation in results from successive samplings is large enough to cause a respectful pause when it is being interpreted.

The field in which this study was carried on was one with a ratoon crop; this indicates that phosphate fertilizer had been applied on these cane rows in the previous crop, in fact the field records show that 250 pounds of P_2O_5 had thus been applied. Since we know that this soil has the power to "fix" this applied phosphate, and as it is unlikely that the previous crop actually took even half of this amount out of the soil, it is obvious that some of the phosphate that was applied to the previous crop remained pretty close to where it was placed, and was there when we started to sample for this present crop. Hence, knowing how unlikely it is that phosphate fertilizer is "thrown" uniformly on the cane row, it is not difficult to explain such variations in results from soil samples taken before fertilizing the present crop at successive semi-monthly periods, as these from:

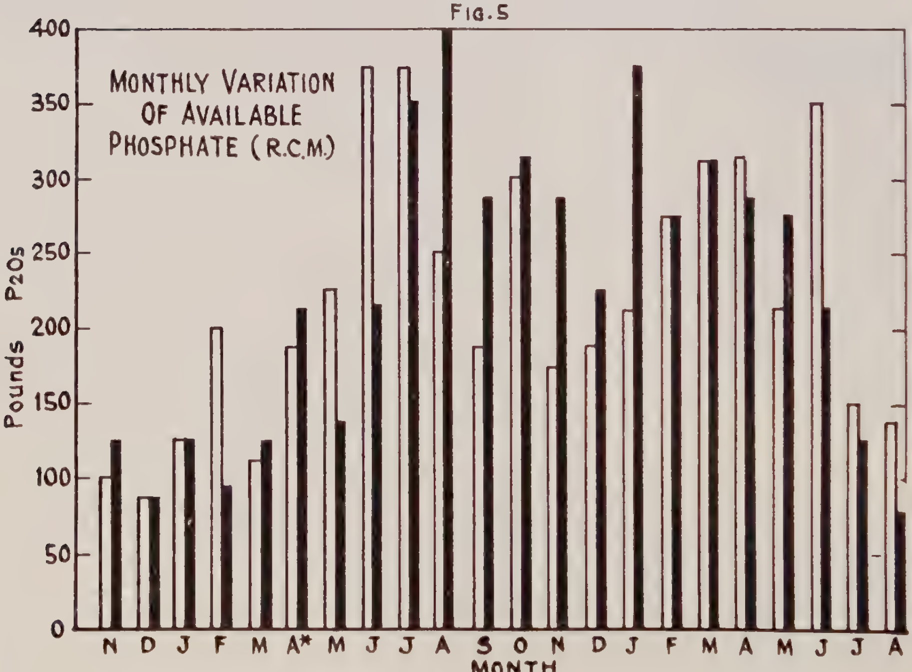
Section A: 100 - 150 - 100 - 300 - 70 - 150, and from
Section B: 100 - 150 - 30 - 150 - 100 - 150 pounds per acre.

FIG. 4



* = Fertilized with Potash Mar. 20

FIG. 5



* = Fertilized with Phosphate Apr. 9

A similar condition is found throughout the growth of this crop we studied, even after we had been especially careful to apply the superphosphate to the cane rows of both Sections A and B in such a way as we thought would tend to reduce this variation in results of soil samples taken later on. And we find such variations in pounds of P_2O_5 (R.C.M.) for successive samplings after fertilization as indicated by these 4 examples, taken at random from Table II:

1. 125 - 200 - 250 - 550 - 200 - 400 - 350
2. 150 - 175 - 250 - 175 - 375 - 175 - 350
3. 125 - 300 - 350 - 350 - 400 - 400 - 225
4. 400 - 400 - 175 - 300 - 150 - 350 - 400

Fortunately these figures are all believed to represent an adequate supply of phosphate and hence the variations in this case may not have a practical meaning, but in the case of the samples taken at the start of the crop, that taken in Section B on February 1, showing 150 pounds P_2O_5 would indicate no real need of phosphate fertilization for this soil, while the next sample taken from the same place 2 weeks later showing only 30 pounds P_2O_5 would definitely indicate a real phosphate deficiency; similarly from Section A, we have a sample taken on March 2 showing 300 pounds of P_2O_5 which is certainly an adequate supply, but on March 14 when only 70 pounds were found, an inadequate supply is indicated; yet 2 weeks later before any phosphate fertilizer had been applied, this apparent deficiency disappeared.

The general trend shown in Fig. 5 is that the available phosphate supply was increased when the phosphate fertilizer was applied in April, and that it remained at a fairly high level thereafter. There was apparently a reduced supply in the second winter, and the supply had quite definitely fallen off in the last 2 months before harvest while the area was being "dried-off for ripening."

The comparative similarity of the phosphate status (R.C.M.) in Sections A and B is indicated by the correlation coefficient of $+.51 \pm .076$; although this is definitely positive, undoubtedly the "sampling error" was an influence.

A correlation coefficient of $+.78 \pm .040$ from Section A and of $+.81 \pm .035$ from Section B indicates the very favorable relationship that exists between the results for phosphate as secured by the Mitscherlich and the R.C.M. analyses of soil samples.

Altogether, the results secured have given us a better idea of: (a) How the availability of nitrogen, phosphoric acid, and potash in the cropped soil is being largely influenced by applications of fertilizers and by crop uptake; (b) The speed with which ammonium fertilizer may be utilized (we assume leaching to be negligible); (c) The difference between the supply of available potash in the cropped soil during the early development of the crop and in its second year of growth; (d) The definite build-up of the soil phosphate supply by fertilization; and (e) The difficulties concerned with securing "true" soil samples for fertility analyses from areas that have been fertilized (especially with phosphates) unless the real conditions resulting therefrom are appreciated and recognized.

TABLE II

Section A

Date	Fertilizer Applied	Pounds per Acre-Foot of Soil* — Phosphate (P_2O_5) Mitsch.	Phosphate (P_2O_5) R.C.M.	Potash (K_2O) Mitsch.	Potash (K_2O) R.C.M.	Nitrogen (N) Mitsch.	Nitrogen (N) R.C.M.	Water Sol.	Total Kjeldahl	pH	P_2O_5 Fixation
Nov. 17, 1934		52	100	520	100	74	30	30	5775	6.4	35
Dec. 3		56	100	564	125	88	20	43	5725	6.6	40
Dec. 17		44	100	518	150	111	23	54	5900	6.2	35
Jan. 2, 1935		63	70	484	125	131	23	28	5925	6.6	40
Jan. 16		86	100	510	150	104	25	40	5650	6.2	35
Feb. 1		48	150	652	275	88	33	28	5650	6.4	40
Feb. 14		60	100	545	225	92	20	10	6000	6.5	40
Mar. 2	50 lbs. K_2O	97	300	1094†	250	97	28	10	5575	6.4	45
Mar. 14	40 lbs. N	64	70	844	250	78	23	10	5775	6.4	40
Apr. 1	200 lbs. P_2O_5	178	150	585	250	73	35	38	6025	6.6	35
Apr. 15		193	250	804	250	88	30	40	5825	6.4	45
May 2		94	125	685	250	64	16	35	5950	6.1	40
May 15	40 lbs. N	108	200	614	150	76	28	40	5900	6.4	40
June 1		196	250	600	150	107	65	54	6025	6.6	35
June 15		298	550	792	100	85	21	35	5850	6.1	30
July 1		135	200	665	100	88	20	23	5750	6.3	35
July 15	40 lbs. N	194	400	699	150	73	38	33	5725	6.2	35
Aug. 1		218	350	671	150	108	58	35	5850	6.0	30
Aug. 15		131	250	522	250	637**	203**	73**	6300	5.8	40
Aug. 31		133	250	474	125	84	38	38	5975	5.8	35
Sept. 16	40 lbs. N	59	200	452	125	88	28	33	5600	6.1	30
Sept. 30		75	175	467	150	104	43	58	5700	6.0	45
Oct. 15		133	300	557	225	106	40	45	5575	6.5	50
Nov. 2		133	300	377	100	102	33	38	5425	6.2	50
Nov. 18		145	...	437	...	80	...	...	....	...	..
Nov. 30		98	175	351	100	75	15	18	5575	6.0	45
Dec. 14		81	150	299	100	90	23	23	5825	6.6	45
Jan. 2, 1936		124	175	281	75	87	23	43	5775	6.7	45
Jan. 15		133	250	360	75	83	15	20	5925	6.8	50
Feb. 8		130	175	372	100	62	18	45	5575	6.0	40
Feb. 15		181	375	417	75	58	23	25	5900	6.2	45
Mar. 2		96	175	429	125	42	16	15	6100	6.2	50
Mar. 16	40 lbs. N	149	350	542	100	79	15	20	5800	6.2	50
Mar. 31		124	275	437	75	68	53	49	6100	6.6	50
Apr. 14		253	350	655	100	82	25	50	5650	6.0	45
May 1		221	275	418	—75	82	33	49	5725	6.0	50
May 15		144	175	417	—75	92	63	98	6000	6.0	..
June 1		204	250	510	—75	118	25	27	6075	6.3	50
June 15		176	350	447	100	101	23	38	5850	6.0	65
July 2		188	350	399	100	83	45	18	6250	6.1	50
July 16		198	150	511	100	42	35	25	5175	6.3	40
Aug. 1		121	150	462	100	56	30	18	5175	6.0	40
Aug. 15		104	150	374	75	93	35	31	5600	6.0	45
Aug. 30		120	125	324	75	41	30	20	4900	6.3	45

* From chemical analyses:
Pounds per acre-foot = p.p.m. x 2.5.
From Mitscherlich analyses:
Pounds per acre-foot obtained direct from proper use in Mitscherlich formula.
** Undoubtedly contaminated by nitrogen.
† Probably in error.

NOTE: The heavy lines in Table II separate the analyses of samples taken respectively before and after the indicated fertilizer was applied.

Section B

Date	Fertilizer Applied	Pounds per Acre-Foot of Soil* Phosphate (P_2O_5) Mitsch.	R.C.M.	Potash (K_2O) Mitsch.	R.C.M.	Nitrogen (N) Mitsch.	R.C.M.	Water Sol.	Total Kjeldahl	pH	P_2O_5 Fixation
Nov. 17, 1934		33	100	645	250	76	18	18	5400	6.4	35
Dec. 3		63	150	564	150	88	20	23	5275	6.6	40
Dec. 17		35	100	665	125	90	23	28	5650	6.1	35
Jan. 2, 1935		84	70	578	150	109	23	30	5500	6.5	40
Jan. 16		89	100	783	150	100	23	28	5225	6.4	35
Feb. 1		78	150	666	250	89	23	28	5225	6.4	40
Feb. 14		42	30	533	200	91	20	10	5675	6.5	40
Mar. 2	50 lbs. K_2O	101	150	851	250	92	28	18	5625	6.4	45
Mar. 14	90 lbs. N	84	100	708	300	72	23	25	5800	6.4	40
Apr. 1	200 lbs. P_2O_5	151	150	873	275	253	125	45	5975	6.5	35
Apr. 15		151	300	634	300	167	73	60	5725	6.4	45
May 2		101	125	756	250	83	23	30	5850	6.4	40
May 15		79	150	618	150	86	28	43	6050	6.3	40
June 1		94	125	655	100	66	23	35	6000	6.8	40
June 15	90 lbs. N	114	125	699	150	98	25	30	5650	6.2	40
July 1		154	300	616	200	241	108	65	5800	6.1	40
July 15		160	350	826	150	156	63	70	5775	6.1	40
Aug. 1		172	350	495	150	107	55	48	5725	6.2	35
Aug. 15		156	400	663	300	1085**	253**	118**	5925	5.9	45
Aug. 31		128	400	792	125	74	28	45	5750	5.9	45
Sept. 16		132	225	608	125	87	20	33	6050	6.2	40
Sept. 30		143	350	583	250	94	43	56	5275	6.0	45
Oct. 15		104	225	729	300	90	23	28	5250	6.7	50
Nov. 2		118	400	533	100	81	23	43	5275	6.2	45
Nov. 18		177	400	552	100	76	23	35	5400	6.2	45
Nov. 30		68	175	567	100	57	18	28	5625	6.2	50
Dec. 14		102	300	417	150	86	25	35	5750	6.4	50
Jan. 2, 1936		86	150	472	100	72	21	45	5625	6.7	45
Jan. 15		168	350	515	150	70	13	23	5525	6.6	50
Feb. 8		180	400	414	100	53	13	38	5475	6.2	40
Feb. 15		185	400	654	75	46	25	20	5875	6.2	40
Mar. 2		105	150	471	150	60	18	18	6100	6.0	50
Mar. 16	60 lbs. N	147	300	702	150	75	25	25	5775	6.1	55
Mar. 31		138	325	503	150	100	98	60	6000	6.6	50
Apr. 14		196	375	591	100	175	98	98	5650	5.9	50
May 1		113	200	537	75	101	85	73	5725	6.0	50
May 15		188	275	506	150	129	48	100	6000	6.2	50
June 1		172	275	623	100	103	25	30	6000	6.4	55
June 15		135	250	560	125	160	43	48	5775	6.1	65
July 2		119	175	513	125	71	35	30	5825	6.0	55
July 16		142	150	511	100	42	40	38	5175	6.0	45
Aug. 1		107	100	554	100	53	35	20	5050	6.2	55
Aug. 15		89	125	367	100	86	30	20	5325	6.2	50
Aug. 30		40	30	456	75	43	33	23	4900	6.1	50

* From chemical analyses:
Pounds per acre-foot = p.p.m. x 2.5.
From Mitscherlich analyses:
Pounds per acre-foot obtained direct from proper use in Mitscherlich formula.
** Undoubtedly contaminated by nitrogen.
† Probably in error.

NOTE: The heavy lines in Table II separate the analyses of samples taken respectively before and after the indicated fertilizer was applied.

West African Notes

By R. H. Van Zwaluwenburg

A steamy-hot rain forest, roughly 100 miles wide, runs along the west coast of Africa for some 1500 miles, from the western shoulder of the continent to Cameroons Mountain, where it widens southward and continues east into Uganda. Believed to be the home of the group of insects to which the Mediterranean fruit fly belongs, the forested belt of West Africa was chosen, under one of the Hawaiian sugar processing-tax projects of the A. A. A., as a source from which to get more parasites to improve the natural control of the Mediterranean fruit fly and of the melon fly in

Fig. 1. The usual way of landing at West African ports. The "mammy-chair" transfers the traveler to a surfboat manned by a dozen paddlers.

the Hawaiian Islands. The trail of fruit flies and their parasites led to Sierra Leone, Nigeria, and the French Cameroons, with shorter stops in Liberia, the Gold Coast, the Belgian Congo, and Angola (Portuguese West Africa).* With J. M. McGough, the writer landed first at Freetown, Sierra Leone** on November 9, 1935.

* A summary of the results of the expedition is given at the end of this article.

** Although Sierra Leone does not lie within the rain forest belt proper, there were good reasons for beginning the work there, and some of the most promising parasite material was obtained in that country.

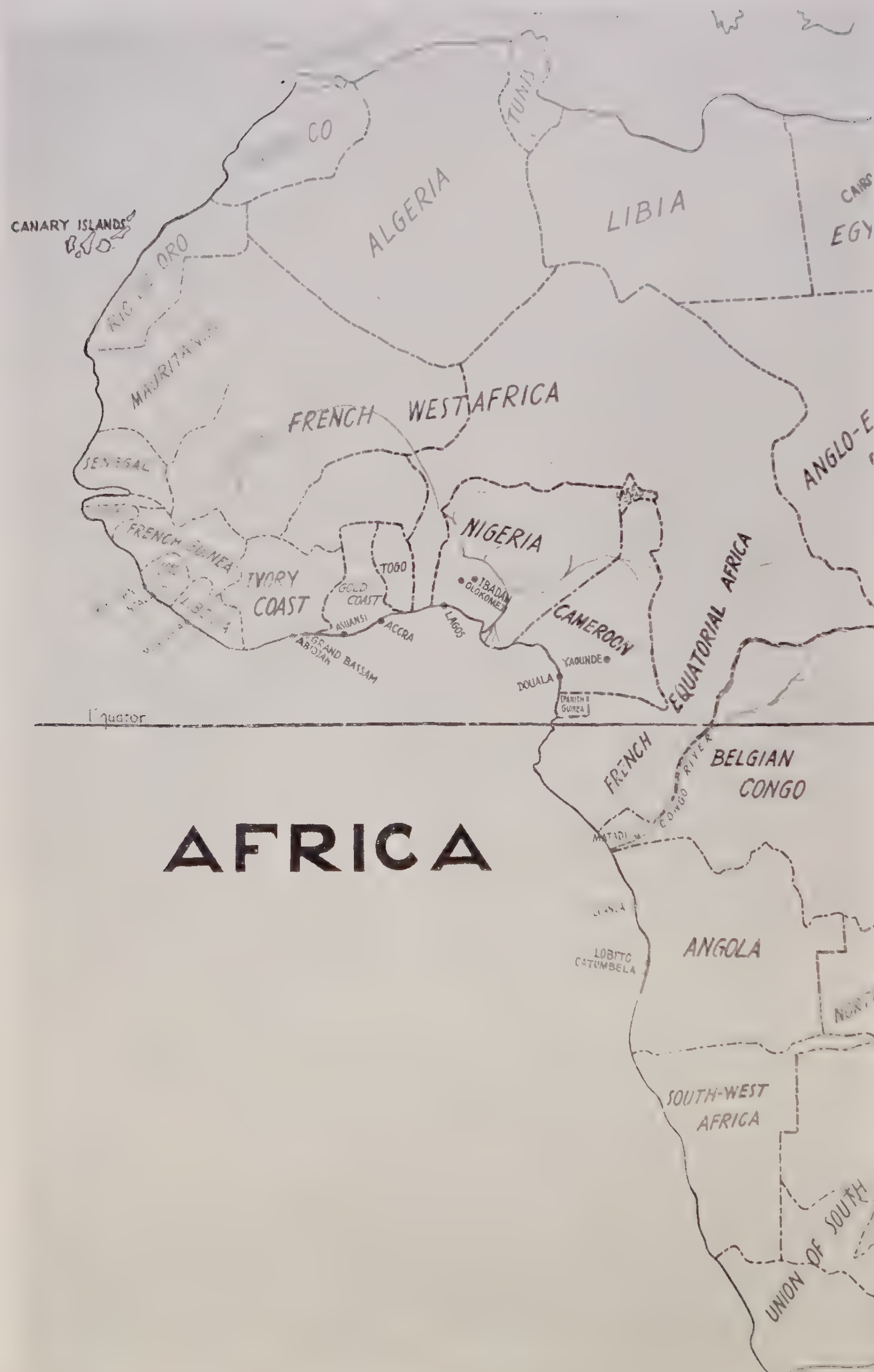


Fig. 2. Map of West Africa showing the regions visited between November 1935 and August 1936.

Climate and Rainfall

The climate of the "Coast" is notoriously trying. Heat is oppressive in the lowlands, where year-round temperatures average in the middle or upper eighties. Only in the Cameroons do mountains occur where relief from the enervating heat can be found. The coolest weather is during the few weeks of January when the steady harmatan blows, but this parching wind off the Sahara is a mixed blessing, looked forward to with dread.

The heaviest rains fall on shore lines which face the southwest: Sierra Leone, Liberia, and the Mount Cameroons region; these districts get from 160 to 200 inches each year. On the east-west part of the Coast, rain is heaviest at the sea and lessens as one goes inland; the reverse is true on the north-south portion below the mouth of the Congo. Between the Congo and the Cameroons there is little difference in rainfall between seacoast and interior. An exception to the general raininess of the coastal districts is the small arc of semi-dry country about Accra in the Gold Coast, where only some 40 inches fall annually.

The well-marked rainy season from April or May into November, is ushered in and out by electrical storms of great severity, accompanied by sudden, fierce gusts of wind.

There is both archeological and geological evidence that formerly Africa was more generally watered than it is today. The obvious sign of the continent's drying is seen on the northern borders of the West Coast colonies, where the Sahara sands each year make small steady advances southward.

Sierra Leone

The Freetown peninsula is the only high land on the coast between Morocco and the Cameroons; so the capital of Sierra Leone, with its backdrop of forested mountains, is a pleasant change after days of coasting past the unrelieved flatness of mangrove swamps and low shore. Freetown was the first colony on the continent to be founded by Africans repatriated from America. Sponsored by William Wilberforce, the English philanthropist, the first settlement was made in the late eighteenth century. Its early years were made difficult by the fierce attacks of local tribes and outbreaks of yellow fever, which, persisting long after the success of the infant colony was assured, took heavy toll of the small population. Today Freetown is a city of some 70,000—"Creoles" (the local name for the descendants of the early immigrants), indigenous natives, and a few hundred Europeans. The Freetown Creole is without firm roots in this part of Africa; neither his language nor his customs are those of the tribes which surround him. His ancestors came to America from the Niger delta, some 1500 miles to the eastward, so he is nearly as much a foreigner in his present location as any white man.

With few exceptions the Creoles are all Christians. Waves of warlike, semitic tribes (Foulahs, Temnis, Mandingoes, etc.), for the most part Mohammedan, have for centuries swept down on the West Coast from the northeast. A few indigenous agricultural tribes like the Mendés, have withstood this pressure, and remain in more or less their original areas. They are mostly pagan, but lately Christians and Moslems have made many converts among them.

Fig. 3. Forested mountains back of Freetown, Sierra Leone; much of the forest shown here is a reserve furnishing the city's water supply.

The Freetown peninsula comprises the Colony, and the back country the Protectorate; together they have a population of well over a million. They are ruled according to the traditional British model of justice and security. Government is indirect, through native paramount chiefs elected for life; direct taxation is confined to a small hut tax. A school system is especially well developed in the Colony; a medical service maintains European physicians in the principal centers, and directs sanitary work. Government school and hospital facilities are augmented by those of the numerous missions. There is a Department of Agriculture, directed by Dr. F. J. Martin, with an experimental farm at Njala in the southern province where a small European staff is engaged in research and extension work. A forestry department is concerned, among other problems, with reforesting burned-over farmland no longer in cultivation.

Despite recent discoveries of platinum, gold, and diamonds, agriculture remains the mainstay of Sierra Leone, a country which has been self-supporting for many years. Oil and kernels of the oil palm *(Elaeis guineensis)*, and kola nuts are the important export crops. Kola nuts contain a powerful stimulant, and enormous quantities to be used by the natives are exported to the neighboring French colonies. Minor produce like ginger, peanuts, and piassava (the fiber of Raphia palms) is of considerable value. All of the above, except ginger and peanuts, are gathered from plants in natural conditions, not under cultivation.

No non-African can own land in Sierra Leone. The land, or "town-bush" of each native settlement belongs to that community, and its particular ownership, either by individuals or by families, is recognized by tribal custom. The typical native

farm, to which the owner and his family go out each day to work, is a mixed planting of corn, cassava, cotton, millet, peppers and miscellaneous food plants. The orchard bush is cleared and burned over before planting, and the ground is farmed for about a year. Moving to a new site yearly, the farmer returns to the first clearing, by now completely overgrown again, in about six years. Smoke columns from clearings being prepared for planting dot the countryside toward the end of the dry season.

Throughout West Africa the native's food habits are based largely upon introduced food plants. Crops introduced during the past five hundred years of contact with Europeans, have to a great extent replaced the native ones. The probably meagre diet of the aboriginal African (palm oil, yams, millet, game and a few native fruits) has been supplanted or added to by introduced foods like corn, rice, cassava, peanuts, bananas and other fruits. Corn has been the staple for so long in Portuguese West Africa that the Angolese believe it is a native plant. Improvement in diet, as well as the stopping of almost constant tribal warfare, may explain the great increase in native populations since the white man has dominated Africa.

The newcomer to Freetown senses a lack of something, without knowing what it is. Finally it dawns on him that it is the complete absence of horses and cattle. Tsetse fly-borne diseases make stock raising all but impossible in Sierra Leone, except in parts of the northern province. Goats and poultry are almost the only domesticated animals raised. The Njala experimental farm, by crossing the "native" fowl with the Rhode Island Red, has produced a strain well suited to local conditions. Fresh beef is imported from French Guinea; cow's milk is almost unknown except

Fig. 4. Oil palm. Growing wild in the heavy rain forest, this plant supplies the kernels and oil which are the backbone of West African commerce.

in cans. All butter is imported, but this necessity concerns only the European, for the native uses palm oil lavishly in all his cooking.

It is said that Sierra Leone's oil palm production might be greatly increased. The Department of Agriculture's large planting of palms near Freetown demonstrates the advantages of cultivation in a crop now entirely "wild." But whatever interest in planting palms this may kindle in the native, is cooled by the low price of oil and kernels. Production records at Njala show clearly that the local palm, which now produces the entire crop, might profitably be replaced by the more productive Nigerian variety.

The Agricultural Department has had notable success in fostering the rice industry. Formerly nearly all of this staple was imported, but now the country produces enough for its own needs, and with large areas of suitable land available, the present small exports of rice will doubtless increase. The cost of the local product is said to be less than that of imported rice from India.

Among the crops the department has tried to encourage by demonstration plantings, is citrus. Oranges and grapefruit of high quality are grown, but a serious problem has been the control of fruit-piercing moths. Adults of some fifty kinds ot noctuid moths pierce the ripening fruit with their long tongues, and a dropping of the entire crop often results. From April to June the moths come to the groves from the "bush," where they have fed as larvae upon a wide range of native plants. The difficulty of discovering and poisoning the feeding grounds, and the migratory habits of some of the species, leave the adult as the only stage against which control can be directed. Ernest Hargreaves, the entomologist at Njala, has developed effective syrup baits for poisoning adult moths. It will interest Hawaiian fruit growers to know that one of the worst species in Sierra Leone (*Othreis fullonica* L.) occurs no farther away from these Islands than Fiji and Samoa.

Pineapples are often on sale in Sierra Leone markets, but are hardly a commercial crop. At Njala a few plants of Smooth Cayenne were seen. They appeared free from insects, but Mr. Hargreaves records two coccids on pineapple: one, the common pineapple mealybug, *Pseudococcus brevipes* (Ckll.), and the other a scale, *Diaspis boisduvalii* Sign. He has found a coccinellid beetle, *Hyperaspis senegalensis* Murr., to be predaceous on the mealybug.

Termites similar to the slow-working, drywood species of Hawaii occur in European-type buildings; their damage is seldom severe. The structures of ground-nesting termites are common in the southern part of the country, but the species apparently do not enter buildings, and no precautions are taken against them. Most native houses are so temporary in nature that they are usually replaced before termites damage them seriously. No effective enemies of termites are known in West Africa. Lizards and a calliphorid fly (*Ochromyia depressa* Walk.), which captures and feeds on stray individuals, prey upon white ants in general. Only when nests are accidentally broken, or flights are in progress, do they have access to them.

The Protectorate native lives much as his ancestors did, unaffected by the white man except for the benefits of improved health and personal security. Native houses are a single story high, usually of wood with walls of wattle and mud and floors of dirt. They are circular or rectangular in shape, according to tribal custom, and the roofs are thatched with grass or palm fronds, or covered with plaited palm-leaf "slates." The pagan native is highly superstitious. He believes that certain indi-

viduals can change themselves at will into wild animals; that the "boman" (actually the large, hammer-headed fruit bat) sucks the blood of children, and after their death turns into either stone or snake. The monotonous cries of these bats, common of an evening wherever ripening fruit occurs, brings out the entire village to drive away the animals by beating on tins, and by vigorous cursing of their parents and all their ancestors. Medicine men claim the power of invoking lightning by means of "thunder-axes" fashioned from meteorites. Secret societies, like the Human Leopard and Crocodile, formerly caused many savage and mysterious crimes, but the British have suppressed such activities. Much store is attached to "making medicine"; it is almost impossible to purchase a leopard skin from which teeth and claws have not already been removed for juju.

Fig. 5. Historic Ceiba or "cotton tree," Freetown; long a landmark for mariners, the slave market was held beneath its shade in former times.

The native takes pride in his person, and seems forever to be bathing. The use of the "chewing stick," a form of toothbrush, is universal; a soft stick (various kinds of wood are used) is chewed into a tuft of fiber at one end, and carried in the mouth during the early hours of the day's routine. Scars made by rubbing ashes into cuts in the skin are a common form of decoration, particularly elaborate among the women. Individuals are seen completely and symmetrically covered with a fine scar-design; the effect is artistic by any standard and to a pagan worth the pain of acquiring. Our Mendé steward boy had his middle upper teeth filed to sharp points, a sign, perhaps, that his father had been a member of a cannibal society.

The most characteristic Sierra Leone native products are the beautiful "country cloths," handwork from start to finish. Native cotton is cleaned, spun

and dyed by women, then woven by the men into distinctive and pleasing designs, usually blue or black on a white background. Basketware and articles of woven raffia and leather are of excellent workmanship. Such articles are colored with local vegetable dyes, a favorite being the red of camwood *(Baphia lobata)*.

The Kissi tribe, originally immigrants from the Sudan region, occupies a remote eastern section of the country and part of Liberia. Conventional money interests them little; their money consists of so-called "Kissi pennies," slender, foot-long rods of native wrought iron. Exchange varies from 12 to 14 for the English penny, but the Kissi prizes his curious currency for the intrinsic value of the iron itself.

Fig. 6. Mendé devil dancer; the costume is of raffia.

While at Njala, hearing the incessant throbbing of dance drums night after night, we went one evening to the nearby village of Mekundé and requested a dance. The chief had retired, but he emerged from his house with dignified courtesy and ordered out the entire village (of some 200 Mendé tribesmen) to perform for us. Surely many of the modern dances are pure African, for that night the unmistakable prototypes of Charleston and rumba were danced with a fervor not given to whites. So pleased was the chief (and all the villagers) with the shilling which we "dashed" him for the entertainment, that he offered to send some 30 miles away for special dancers if we would return the next day.

The following afternoon we were again seated on either side of the chief, before the "barri" or palaver-house. Then began a dance pantomime centering about a male and a female devil. Both wore raffia costumes which completely covered them, and grotesque wooden masks. The symbolism was clear to the

native spectators, but for us, in spite of a somewhat involved explanation by an interpreter, it was difficult to follow. It had something to do with the rites of the Porro and Bundu societies, the secret tribal organizations of the men and women respectively. Both devils seemed harmless characters, although the male demon, with sudden leaps and outcries, scared into frightened wails most of the small children who watched breathless from the sidelines. The man devil was made the butt and laughingstock of the afternoon by a ten-year old boy dancer who supplied comedy relief by impudent grimacing and teasing. Later we had a chance to observe that the impudence allowed this youngster by his dance rôle had no part in the everyday life of this well-mannered, African small boy. Throughout the long hot hours of the afternoon, the drumming (done with fingers or the palm of the hand) continued without a break, even during the intervals when the dancers rested.

Fig. 7. Mendé village, southern province, Sierra Leone, showing the native architecture.

Liberia

The Republic of Liberia, the only remaining independent country in Africa, is of special interest to Americans. American philanthropic societies bought land along the Liberian coast from native tribes for settlement by negroes from the United States. The first colony was founded in 1821; others soon followed, and in all, four or five separate settlements were made. Because of difficulties arising from their vague international position, the colonists finally united to form a republic in 1847. Great Britain recognized Liberia the following year, but the United States did not take similar action until 1862. There has been almost

no immigration into Liberia since the American Civil War. The relatively few descendants of the immigrants from America (locally called "Liberians" to distinguish them from the indigenous natives), some 20,000 in all, are the dominant class in the country. The natives, totalling perhaps a million, contribute an increasing number to the ruling class as their opportunities increase, but in general, government and economic control are in the hands of the American-Liberians.

The language of the educated Liberian is American, and his cultural background American rather than European. The influence of the Old South is plainly seen in the architecture of Monrovia, and to some extent the social and economic ideas of the same section have also survived. The original ideal of a country of small independent farmers seems largely to have been lost sight of, and among the well to do there has arisen a leisured planter class.

Fig. 8. Typical better-class residence, Monrovia, Liberia.

Liberia is about the size of the state of Ohio, and lies almost entirely within the rain forest belt. There is a relatively small proportion of grass land to forest. Numerous short rivers lead into the interior, and these afford the only communication with the back country except for trails. Roads are being extended, but improvements of this sort, as well as the bettering of educational facilities and health conditions are hampered by lack of money.

The only large concession is that of a large American rubber company, which has obtained the right to plant up to a million acres. Its several plantations are devoted to Hevea rubber, and production is mounting annually; its largest area, with perhaps 100,000 acres already planted, is near Monrovia. The company depends almost entirely on its own rubber, but encourages production by native

Fig. 9. Market stall, Waterside, Monrovia; the stock in trade here consists of pineapples, bananas, avocados, and peanuts.

Fig. 10. An umbrella shades this vendor's stock of merchandise in the Monrovia market.

growers also. Despite a potentially large labor supply, one of the chief difficulties is maintaining an adequate force of natives.

Liberia suffered acutely from the disruption of commerce attending the World War, and only lately has recovery begun. The country's reliance in the past has been upon exports of agricultural produce (palm oil, palm kernels, and coffee principally), but with the wartime experience in mind, it is probable, according to students of the country, that in the future Liberia will tend to become more self-sustaining and to develop more of its native resources.

Among the indigenous tribes of Liberia the Kru race is exceptional. Originally farming tribes like the rest of the indigenous natives, the Krus have gained a reputation as seafarers, and man all the European vessels running along the West African coast. They still wear a tattoo mark on the forehead, a relic from less secure times when it exempted them from capture and forced labor.

Gold Coast

For over 200 years the Gold Coast was the scene of the bitterest commercial rivalries between Portuguese, Swedes, Brandenburgers, Dutch, and English. Traffic in natives attracted merchant companies more strongly than even the gold deposits. For the protection of their traders the companies erected great castles along the coast, some of them as early as the fifteenth century. A few, like Elmina and Cape Coast castles, are still in excellent repair, and in use today for government purposes; Christiansborg castle, near Accra, is the residence of the governor. These stately structures are everything demanded by romantic notions of what a

Fig. 11. Termite nest, Njala, Sierra Leone; the species is probably *Cubitermes silvestrii* Sjöst.

castle should be—moats, drawbridges, enormously thick walls, battlements, barracoons, and dungeons.

Private ownership of land does not exist in the Gold Coast; land is community property and its use is allocated by the chiefs according to tribal custom. The system has been slightly modified to permit the longer tenure necessary to crops like cocoa, but the land is still communal. As in all the British West African colonies no land is available to anyone not of African blood. Gold Coast natives seldom have to hire out as laborers, so the companies engaged in mining import labor from the nearby French colonies.

Cocoa, palm oil (and kernels), and kola nuts are the leading agricultural products of the colony. Cocoa not only overshadows all other farm products, but the mining output as well. Starting from almost nothing, cocoa production has increased within the past 25 years until it is now nearly half of the entire world crop of some 600,000 tons. All is produced by small peasant communities, and comes from the southern part of the colony where the annual rainfall is from 60 to 70 inches. Formerly Gold Coast cocoa was of low quality, but since the development of the Department of Agriculture's inspection service, rejections of export cocoa have dropped to about 12 per cent. Among the cooperative societies sponsored by the department, the quality is even higher, rejections being but 2 per cent. Rejections are usually for fungus and insect damage (the latter mostly due to *Araeocerus fasciculatus* De G. and *Ephestia sp.*), for imperfections of color, improper fermentation, etc.

The Department of Agriculture, directed by G. G. Auchinleck, is staffed by 45 Europeans and some 100 natives. Besides inspecting export farm products, it organizes and gives financial aid to small cooperative groups (of which about 3,000 have been formed in the cocoa industry), maintains statistical records for all crops, and carries on research at its main station at Aburi, near Accra, and at its Assuansi fruit farm in the western province. At the latter station the normal 8-year cycle of general agricultural practice has been cut in half by using *Centrosema pubescens* as a covercrop. By pasturing native sheep on another legume planted in citrus orchards, the station maintains fertility at a high point and incidentally produces an extremely cheap mutton. Native farmers approached on the subject of covercrops, demand first that the covercrop be edible; such a crop, a native species of Mucuma, has been found at Assuansi. None of the various kinds of pigeon pea tried has done well in the Gold Coast. Near Assuansi is the plant of a well-known producer of lime juice, a firm now withdrawing from the West Indies to concentrate in West Africa; all its fruit is purchased from natives.

The Gold Coast is one of the most obviously progressive of the West Coast colonies. A recent governor, the late Sir Gordon Guggisberg, a Canadian by birth, left an impressive monument of public works, at a cost of some 9 million pounds. Besides extending the railroad system and the network of paved roads, he built a breakwater and modern harbor at Takoradi, and at Accra, the Korlebu native hospital which is the last word in hospital planning. He built also the magnificent Achemota College to which come natives of both sexes from all parts of West Africa to study from kindergarten on, through such specialized courses as law, medicine and engineering.

Nigeria

More than three times larger than Great Britain itself, Nigeria, with its 20 millions, is the most populous of all the British colonies in Africa. It is a land of plains lying almost entirely within the basin of the Niger river. There is a wide coastal belt of swamp and mangrove country, then a heavily forested belt, above which lies the greater part of the country, an undulating plateau of grass and bush.

Its principal agricultural products have long been palm oil and kernels, and livestock. Stock is raised principally for milk and hides, beef production being unimportant; the industry, because of tsetse fly in most of the country, is confined to the northern part of the colony. Farmers rarely own livestock; most of it is raised by pastoral tribes not engaged in any other sort of agriculture. Since the war, cocoa, peanuts ("groundnuts"), and cotton have been developed into major importance. Further increase in oil palm production is said to depend upon solving labor problems involved in the gathering of the wild crop over enormous tracts of forest.

The Department of Agriculture has its main experimental farm at Moor Plantation, near Ibadan, a city of about a quarter of a million, said to be the largest native town in Africa. Several other stations are located at various points about the country. To maintain soil fertility the department is trying to increase the use of cattle on farms, and to encourage crop rotation. At the Ibadan farm an unusual use was being made of corn; it was grown as an indicator crop in soil fertility tests. Most native farms are extremely small, and cultivation consists of a superficial hoeing; there is much more land available than can at present be used.

Migratory locusts are the worst single pest of general agriculture. Their principal breeding grounds are in the Lake Tchad region, and the Nigerian Department of Agriculture has, for several years, conducted a project of investigation and control in cooperation with the French authorities within whose territories the "hoppers" hatch.

There are over 50,000 square miles of rain forest and fringing forest in southern Nigeria, all administered by the Nigerian forests department. Operations are supervised by European forest officers who designate which trees shall be cut. Important timber trees are "African mahogany" *(Khaya ivorensis)* and "West African (or Sapele) mahogany" *(Entandophragma cylindricum)* which is heavier and harder than the other African "mahoganies." Large amounts of *Lophira alata* are cut for railroad ties. In the forest reserve at Olokemeji in southern Nigeria are large plantings of oriental teak, some of them over 25 years old; they have made good growth, but no commercial use has been made of them.

Colonies of a termite with nasute soldiers, nesting in low mounds, were common in the open country about Olokemeji. The upper galleries in the structures built by this species invariably contained quantities of grass cut into nearly uniform lengths. It was in the forests that we found columns of the driver ant *(Dorylus spp.)* most common. The compact mass of the main column streams blindly along, fringed by a less conspicuous screen of scouts which quickly rout the observer, along with smaller animal life, out of his complacency. The

Fig. 12. Native structures used for storing corn, near Ibadan, southern Nigeria.

Fig. 13. Native market, Olokemeji, southern Nigeria. The large bundles are raffia used as pads under head loads.

large, cylindrical, winged males of the driver ant are a common feature of West Africa, flying clumsily about lighted rooms at night; they are known as "sausage flies."

One day while traversing a path which emerged from the forest near Ibadan, we observed a very large wasp, *Hemipepsis heros* Guer., flush out of the grass a specimen of the mouse-large cricket (*Brachytrypes membranaceus Drury*) which is a serious garden pest as far westward as Sierra Leone. After grappling with the cricket for some moments, the wasp paralyzed it, and was in the act of dragging it off, presumably to an underground burrow, when it was captured. The cricket was kept several days, but died without regaining activity. The psammocharid group to which Hemipepsis belongs generally stocks its nests with paralyzed spiders; the above observation (the wasp was compared with named material in the entomological collection at Moor Plantation) indicates that there are exceptions to the general rule.

In eastern Nigeria, in that part of the former German Cameroons now administered by the British as a mandate from the League of Nations, occurs the only exception to the British West African policy of land for the natives only. Large land concessions were made to Europeans before the war, and have remained unaltered since. The planters are mostly Germans engaged in banana culture; production has increased so greatly of late years that there is now a line of fast steamers taking the fruit direct to Europe.

French Cameroons

Even more picturesque than Freetown after the monotony of flat coastline, is, having passed a hundred miles of muddy-mouthed Niger delta, to steam between the 13,000-foot peak of Cameroons Mountain and the Spanish island of Fernando Po. East of and behind the majestic mountain, the ship enters the muddy flats of the Wuri river, twenty miles up which lies Douala, the chief port of the French mandate. The town lies on a low bluff in the midst of swamps and high forest which in many places comes to the water's edge; it is important commercially, and the starting point of the railroad. Some 200 miles inland one branch of the line, after winding up into the mountains, ends at Yaoundé, the capital, where it connects with an enormous motor road system. In one direction a road runs along the back of the British colonies westward to Dakar in Senegal; in another to the French outposts in the Sahara; in a third, south into equatorial Africa; and finally in another, through the Belgian Congo into Uganda.

The familiar oil palm, in the Cameroons as elsewhere, is the backbone of commerce. For the most part a wild forest crop, there are plantings of it in the Mount Cameroons region. Next in importance come cocoa, timber, and rubber. Most of the rubber is obtained from Landolphia and *Kickxia elastica* growing wild in the forest, but there are a few pre-war plantings of Kickxia as well as of the Brazilian Hevea.

The Cameroons is largely peopled by Bantu stock, a race occupying the entire breadth of Africa from there to the Cape of Good Hope. In this mandate they build long, rectangular houses with walls of bamboo or palm splints lashed grid-like and plastered over with mud; the roofs are covered with units of plaited palm

Fig. 14. Raphia palm, Lumley Beach, Freetown. A versatile tree from which are obtained piassava fiber and palm wine.

Fig. 15. Young leopard, Sierra Leone; the West African variety is much darker than others of the same species occurring elsewhere on that continent or in India. This leopard is now in a zoo in the eastern United States.

leaves. Ventilation is through the single door and the very small window placed just under the roof-peak at either end of the house. Villages are commonly strung along the road, one house deep, with clearings cut out of the high forest behind the houses. A town thus forms a single long street, sometimes miles long.

Well-made crossbows are used for hunting small game; the strong tension of the string is released by a simple trigger device. The arrows, which are unfeathered, are highly prized, and a hunter will search for hours to retrieve them. This weapon is said to be indigenous to this part of Africa, and not copied from the medieval European crossbow which natives might supposedly have seen in the hands of early voyagers.

To find clear traces of Uncle Remus in the Cameroons, was one of the most pleasant of many surprises. We heard several Ewonde native stories which differ from those of Joel Chandler Harris only in local substitutions for the familiar Br'er Rabbit and Br'er Wolf. Similar legends are widespread on the West Coast, and it seems not improbable that the Georgia plantation stories are direct importations from Africa, modified only to fit a new land.

A higher proportion of Christian natives is said to be present in the Cameroons because mission work has been carried on longer there than elsewhere in West Africa. The missions have numerous schools and hospitals throughout the mandate, those of the American mission at Ebolowa, founded in 1885, being among the longest established.

Yaoundé, at an elevation of 800 meters in hilly country, lies between rain forest and grass savannah. In spite of some blackwater fever, it is healthier than the hot lowlands, and is a favorite rest resort for officials from the coast towns. Douala and Yaoundé are attractive towns, planted to many kinds of native and introduced ornamental plants. It was surprising to observe the wide use of panax and hibiscus, the latter said to have been brought from Hawaii during the German regime. Throughout the country, and in the colonies to the west as well, lemon grass *(Andropogon schoenanthus)* is planted to hold soil on road shoulders and railroad embankments.

Wild life finds a paradise in the Cameroons. Even from the train it is not unusual to see troops of mango monkeys, the gray African parrot in solitary flight, its wingtips a vivid red, or the grotesque hornbill, sentinel-like on a commanding treetop. Although the highlands are the home of gorillas and elephants, we personally saw neither. At one plantation the owner complained that elephants had run through his garden the night before; we saw fences and small shacks demolished or pushed over, the plantings completely ruined.

A yellowish variety of the oriental ant, *Oecophylla smaragdina* (Fabr.) which occurs throughout West Africa, was conspicuous about Douala and Yaoundé. This ant nests within clusters of tightly-webbed leaves; the foliage is fastened together by silk secreted by the larvae, which are employed like shuttles by the workers to bind the leaves together. This insect is very common in citrus trees, and being large and vicious, defends its colonies with effective vigor.

Another ant, smaller and darker than Oecophylla, was seen in large groups on bare, unwebbed foliage. When alarmed it bent its abdomen upward, and with feet firmly braced, jerked rapidly forward and back in perfect synchrony, the

Fig. 16. Nest of unidentified termite, southern Nigeria.

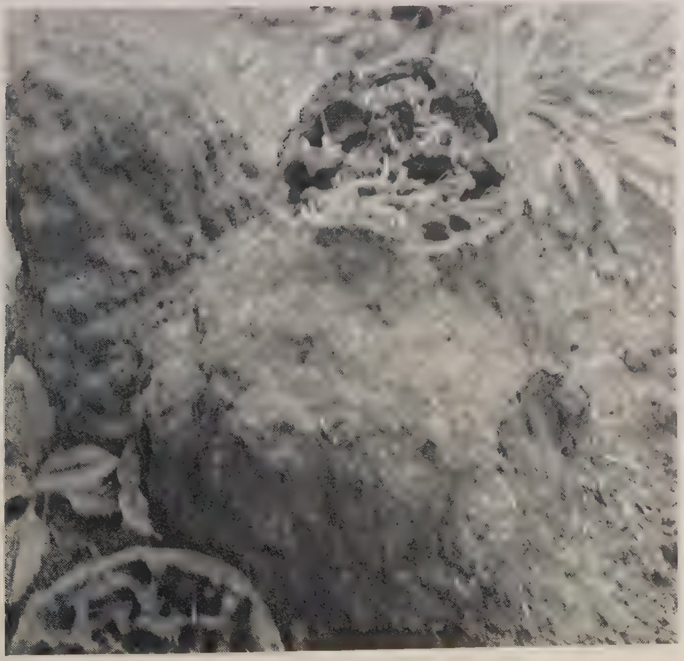


Fig. 17. The same nest opened, showing stores of cut grass in the upper galleries.

many ants moving as one; a plainly audible sound almost like a hissing accompanied these maneuvers.

The Cameroons medical service is highly developed, with particular attention paid to sleeping sickness. One of the worst centers for this disease is in the Ayos district, east of Yaoundé. To Ayos every medical officer just out from France goes to acquaint himself with the newest developments in the treatment of the disease. To leave the Mandate, by steamer at least, the traveller must have an official statement that he is free from sleeping sickness.

White French settlers are fairly numerous in the Cameroons. The result is an atmosphere quite different from that in the neighboring British colonies where the white population is largely official and essentially temporary. The white man in British West Africa leads a divided life; his children, and part of the time, his wife, remain at home in Europe. The Frenchman in the Cameroons, on the other hand, whether because of better climate or the opportunity to own land, establishes his home and family on his mountain plantation or timber concession, and seems to look forward with less urgency than his colonial neighbor to the distant time when he leaves Africa for home and a comfortable retirement.

"The White Man's Grave"

No discussion of West Africa is complete without some comment on health conditions. The medical and sanitary services of the West African colonies are well organized and of high caliber. Modern medical science has erased Sierra Leone's old stigma of the "white man's grave"; but in spite of improvement, West Africa is not a healthy place for the Caucasian. It is particularly trying on children, and in the British colonies none of the white officials are permitted to have their children with them.

The high humidity and enervating heat tax the European's strength and often pave the way for the onset of diseases peculiar to the country. Malaria, dysentery, and parasitic worms are perhaps the commonest maladies. Yellow fever, less frequent now than formerly, still threatens the entire Coast; sleeping sickness, usually a disease of natives, is confined to comparatively small and restricted areas.

The control of malaria, because of the magnitude of mosquito control over enormous areas of wild country, depends almost entirely upon quinine prophylaxis; most Europeans take this drug daily throughout their entire stay. The soft-leather, knee length mosquito boot, almost universally used by the whites in the British colonies, effectively wards off attack. Prevention of mosquito breeding is restricted to European communities and their immediate surroundings. The difficulties of such work on a larger scale are aggravated by the discovery of a malarial vector, the larva of which gets its air through the stems of aquatic plants, a habit making treatments with oil or arsenic ineffective. The newcomer to Freetown is apt to minimize the importance of malaria because of the comparative scarcity of mosquitoes. However, the Sir Alfred E. Jones Laboratory of the Liverpool School of Tropical Medicine, has found that the malaria-infectivity of mosquitoes about Freetown is very high, about 35 per cent. Most of the West Coast malaria is of the malignant tertian type, and the most prevalent vector,

Fig. 18. Native market, Freetown.

Fig. 19. Native market, Freetown; the woman on the left is selecting Kola nuts from the tray.

Anopheles gambiae Giles. Associated with malaria in some imperfectly understood way, is blackwater fever, said to be particularly frequent in the Cameroons.

As a result of its work in Nigeria, the Rockefeller Institute has developed a serum treatment believed to afford certain protection against yellow fever. It has been used only a few years, but it is said that none of their laboratory workers on yellow fever who have received the treatment have contracted the disease, while previously a few became accidentally infected every year. Immunity is presumably lifelong. Treatment is obtainable at present only at the Institute in New York and at the Wellcome Bureau of Scientific Research in London. The Imperial Airways, recently opening a line from Khartoum to Lagos, gave the serum to all of its crews on the West African run. If, as seems probable, the resident of those regions over which yellow fever now hangs as a permanent dread can eliminate so simply the possibility of this disease, a forward step of tremendous importance has been made.

Fruit Fly Investigations*

Nine months on the "Coast" resulted in getting alive to Honolulu 750 braconid wasp parasites of the larval stages of several kinds of fruit flies; they represent about a dozen parasites new to Hawaii.** These parasites are not necessarily specific upon a single kind of fruit fly, and at least some of them from other species can adapt themselves to the Mediterranean fruit fly (*Ceratitis capitata* Wied.). Two (*Opius perproximus* Silvestri and *Biosteres caudatus* Szepl.) have been released in numbers sufficient to give them a good chance of establishment here.

Our stay in Sierra Leone and in the Cameroons coincided with fruiting seasons of many wild fruits; in the other countries visited we were either too late or too early for the best results. When ripe fruit was available, getting parasites was fairly simple; the problem, even with relay stations in the United States where they were fed en route, was to keep them alive across the 9,000 miles between Africa and Honolulu. Personally conducted shipments were the most successful; a laboratory was improvised aboard ship which usually had a chill room available, and there the wasps were reared and cared for until their arrival in the eastern United States.

The Mediterranean fruit fly appears to be rare in the countries covered by this report. Only two specimens were captured, both in southern Nigeria, and nowhere did we breed it from fruit. It had previously been recorded from Togo, Nigeria and the Belgian Congo, but the only breeding record for the species in West

* The flies named in the following have been identified by C. T. Greene of the United States National Museum. Parasites named to species were identified by C. F. W. Muesebeck; the rest have not yet been authentically identified. The search for fruit fly parasites in West Africa and elsewhere was under the direction of C. P. Clausen, in charge of foreign parasite introduction for the Bureau of Entomology and Plant Quarantine, United States Department of Agriculture.

** Previous work by Dr. Filippo Silvestri, D. T. Fullaway and J. C. Bridwell, in 1912-1914, resulted in the establishment in Hawaii of the following African parasites of fruit flies:

Opius humilis Silvestri (larval parasite).
Opius (*Diachasma*) *fullawayi* (Silvestri) (larval parasite).
Tetrastichus giffardianus Silvestri (larval parasite).
Galesus silvestrii Kieffer (pupal parasite).

Africa is by G. S. Cotterell from citrus in the Gold Coast. The native host fruit of this fly therefore remains to be discovered, unless it is coffee, from which it has been bred in East Africa.* We doubt if its real home is in the West African lowlands; it is more probably in the mountainous forests of equatorial or East Africa.

Fruit flies are of little economic importance in West Africa because they are usually in wild fruits of no value; an exception is the dacine (melon fly) group which is a severe pest of cucumbers and other cucurbits. Support was found for the belief that the ceratitine group (*C. capitata* a prominent exception) is indigenous to this part of Agrica. Flies of this subfamily, as well as their parasites, were common only in native fruits; in the rare cases that they infested non-native fruits, their parasites apparently had not followed them into the new plant hosts. Dacine flies, whether in introduced or (more rarely) in native fruits, were seldom parasitized.

There follows a discussion of the principal sources of fruit flies found in the various countries.

Sierra Leone

(Nov. 9, 1935-April 4, 1936; July 23-28, 1936)

Nearly 100 kinds of native and introduced fruits,** totaling many thousands, were examined for fruit flies at Freetown and Njala without result. Infestation was confined to a comparatively small number of host species, most of them indigenous African plants.

Momordica charantia L. Family Cucurbitaceae. Fruits collected at Freetown in July yielded specimens of *Dacus brevistylus* Bezzi, *Dacus ciliatus* Loew and *Dacus* near *punctatifrons* Karsch; no parasites were obtained. The plant is not African, but occurs widely throughout the tropics.

Cucumbers. Obtainable throughout the year, this vegetable is very heavily infested by *Dacus pectoralis* Walk. Large numbers of flies were obtained, but parasitization was almost nil. From 400 puparia obtained in December, 3 specimens of Opius were bred, but 100 per cent emergence of flies was usual in many large lots of puparia.

Passiflora foetida L. Another widely distributed plant not native to Africa. Fruits ripen throughout the year; they seldom drop, even when infested. A single species of fly, *Dacus punctatifrons* Karsch, was reared from this material. At Njala there was one case of parasitization (by *Tetrastichus giffardianus* [Silv.], a parasite previously established in Hawaii) out of 1356 puparia, while at Freetown no parasites whatever were bred from similar material.

Sarcocephalus esculentus Afzel ("Sierra Leone peach"). Family Rubiaceae. Indigenous from Senegal to Angola, eastern Sudan and Uganda; a tall tree under forest conditions, but in orchard bush a scandent shrub attaining 20 feet. The large, reddish fruit has two main ripening seasons in Sierra Leone: November into

* By the late A. H. Ritchie.

** Thanks are due to F. C. Deighton, mycologist at Njala, for the identification of most of our Sierra Leone plant material.

February, and May into August; a few ripe fruits can usually be found at any time of year.

The only trypetid bred from this fruit was *Ceratitis giffardi* Bezzi (*C. cosyra* Walker).* Egg laying takes place even while the fruit is green and very hard; infestation is fairly heavy. Fruits at Njala in November showed 42.8 per cent parasitization by three species:

Biosteres caudatus—21.7 per cent (72 males, 133 females)
Opius perproximus—16.9 per cent.
Tetrastichus (prob.) *giffardianus*—4.2 per cent.

Chasalia afzelii K. Schm. Family Rubiaceae. A shrub, doubtfully indigenous, which we found only in Sierra Leone; the berries ripen in November. From 40 fruits at Njala were obtained 28 puparia of *Ceratitis (Trirhithrum) coffeae* Bezzi and four females of an all-black braconid.

Conopharyngia longiflora Stapf. Family Apocynaceae. Indigenous from Senegal to the Ivory Coast. Ripe fruits were most common from November to February, but a few can usually be found the year round. *Ceratitis punctata* (Wied.) was the only fly bred from this fruit, and infestation was usually light. *Opius perproximus* and *Hedylus giffardi* Silv. were obtained from puparia of flies in this fruit.

Adenia lobata Engl. Family Passifloraceae. An indigenous woody climber ranging from Senegal to Spanish Guinea and Angola. Fruits ripened at Njala in November, and at Hill Station, near Freetown, in July. An undetermined species of Tridacus was bred, but the mortality of larvae before pupation was invariably high; no parasites were obtained. This is the one instance in Sierra Leone of a dacine fly breeding in a native fruit.

Coffea liberica Bull ex Hiern. Family Rubiaceae. Cultivated from Senegal to Angola, and said to be indigenous to Liberia. Berries collected near Freetown in December were lightly infested by *Ceratitis (Trirhithrum) coffeae*, and a single adult Opius was obtained from the same material. Berries were immature in July.

Chrysophyllum pruniforme Engl. Family Sapotaceae. A tall, indigenous, forest tree from Sierra Leone to Angola, and from Kenya to Natal. In Sierra Leone there is a single crop yearly (December to March) of round fruits somewhat over an inch in diameter. Infestation by *Ceratitis punctata* was extremely heavy, with an incomplete record showing an average of nearly 18 maggots per fruit.

Of the 4007 puparia collected in December, 17.9 per cent had been parasitized:
Opius perproximus—699 (288 males, 471 females).
Hedylus giffardi—20.
Tetrastichus—2.

From 19,751 puparia obtained in January and February, the following emerged:
Opius perproximus—12.6 per cent (855 males, 1635 females).
Hedylus giffardi—1.1 per cent (50 males, 172 females).

---

* A few specimens of *Ceratitis (Trirhithrum) coffeae* Bezzi were bred from this fruit, but in insignificant numbers.

Opius greatly outnumbered Hedylus in these two cases, the totals of both records being, Opius 3189, Hedylus 244.

Anisophyllea laurina R.Dr. Family Rhizophoraceae. Indigenous to French Guinea, Sierra Leone and Nigeria. Confined to the coastal region (up to 800 feet or more) in Sierra Leone, it has a single annual crop, ripening abundantly in March. Infestation by *Ceratitis anonae* Graham was fairly heavy, but parasitization (by a single unidentified Opius) was disappointingly low.

Nigeria

(April 17-May 17, 1936)

At Moor Plantation near Ibadan numerous insects were attracted for a few days to the nectaries of *Gliricidia maculata,* a legume planted as a windbreak. Among them were these fruit flies:

Dacus vertebratus Bezzi
Dacus ciliatus Lw.
Ceratitis sp. near *cosyra* Walk.
Ceratitis capitata Wied.
Ceratitis anonae Graham.

The only infested fruits procurable at Moor Plantation were a very few *Momordica* probably *charantia* L. From these were bred *Dacus brevistylus* and the following parasites in order of their numbers:

Opius sp. (reddish body, black head)
Braconid with ovipositor about as long as in Hedylus
Biosteres (probably) *caudatus*

In the forest reserve at Olokemeji our second specimen of *Ceratitis capitata* was taken by sweeping the foliage of a forest path; *Dacus rufus* Bezzi (?) and *Carpophthoromyia n. sp.* were obtained similarly.

The following ripe fruits were available at Olokemeji:

Napoleona probably *vogelii* Hook. and Planch. Family Lecythidaceae. A native shrub or tree up to 50 feet, ranging probably from Sierra Leone to Nigeria; the main crop ripens, we were told, in July. From it were bred *Ceratitis punctata* and *Conradtina acroleuca* Wied., as well as the same parasites apparently as were obtained from Momordica at Ibadan:

Hedylus-like braconid
Opius sp.

Parasitization in this fruit totaled less than 5 per cent.

Landolphia sp. Family Apocynaceae. Two fruits were obtained, from which was bred *Ceratitis capitata,* but no parasites.

Adenia sp. (?) A passifloraceous vine unknown to the forest officers, but much resembling *A. lobata* of Sierra Leone. *Tridacus pectoralis* (Walk.) was bred in considerable numbers, but no parasites.

Conopharyngia penduliflora Stapf. Numerous *Ceratitis cosyra* Walk. were bred from this apocynaceous fruit, but there were no parasites.

French Cameroons

(May 20-June 20, 1936)

If further study of African fruit fly parasites is ever considered, Yaoundé would be an excellent site for a laboratory. Located between rain forest and tree savannah at an elevation of some 2500 feet above the sea, the good roads in all directions, the variety of the vegetation, and the comparative coolness of the region, form a combination unequaled in the lowlands of West Africa. A wider variety of parasites seemed present than in any other place visited. This was also true of the fruit flies; during a single day in the forest, the following were swept from foliage:

Tridacus bivittatus Bigot
Carpophthoromyia n. sp.
Bistrospinaria fortis Speiser
Ceratitis sp., near *cosyra* Walk.
Ceratitis punctata Wied.
Ceratitis anonae Graham

In late May forest fruits were coming into season about Yaoundé, and although many were uninfested, the following were found with fruit flies:

Myrianthus arboreus P. Beauv. Family Moraceae; Yaoundé name "ngakom," a large tree usually in damp places in the forest, ranging from Sierra Leone to Uganda, and south to Angola. The large composite fruits, yellow when ripe, attain a diameter of about five inches. *Ceratitis anonae* was the only fly reared from large quantities of fruit, but infestation was fairly heavy. The following were bred from Myrianthus fruits:

Tetrastichus (probably) *giffardianus*
Biosteres (probably) *caudatus*
Hedylus-like braconid with long ovipositor and black head; general color reddish.
Two specimens of a hymenopteron, probably hyperparasitic.

A group of not less than 1000 puparia of *C. anonae* from Myrianthus showed a total parasitization of 50 per cent; 17.5 per cent was by Tetrastichus.

Conopharyngia spp. Infestation was fairly light; three flies were obtained: *Ceratitis punctata, C. anonae* and *Carpophthoromyia n.sp.* The following parasites were present:

Tetrastichus (probably) *giffardianus*
Biosteres (probably) *caudatus*
Hedylus-like braconid; reddish with both head and abdomen black.

Cola spp. A few kola pods were found, heavily infested by *Ceratitis anonae*. From them were obtained Biosteres and the same Hedylus-like wasp bred from Conopharyngia.

Unknown forest fruit about the size, shape and color of a large olive; Yaoundé name "mbazo'o". Few fruits were infested, but those fairly heavily by *Tridacus*

humeralis Bezzi. From them were bred Biosteres and a single female of a reddish Opius.

Avocado. A few heavily infested fruits of a thin-skinned variety obtained from a native garden near Yaoundé, yielded *Ceratitis anonae,* but no parasites.

Mr. McGough, remaining in Yaoundé until August, obtained there the following additional fruits containing flies and, in some cases, parasites:

Guttiferae. Working with two species of fruit, from both of which he bred Ceratitis, Mr. McGough obtained from the larger, two braconid species, one black, the other red.

Gourd. Dacus sp. and an Opius (?) and a Biosteres (?) were bred.

Squash. A species of Dacus, but no parasites.

Eggplant. A Dacus and a small Hedylus-like parasite.

"Abam," unknown fruit. A Ceratitis was bred from this, and two parasites: Biosteres and Hedylus.

At the same season that ripe fruits were plentifully available in the Yaoundé district, a thorough search of the lowland forests near Douala was unproductive. The only ripe fruit abundant was of a dooryard tree, everywhere present but uninfested; known to English-speaking residents as "bush butter" it definitely was not Butyrospermum. In the rain forest was found a single infested fruit from a small unidentified tree; the fly maggots in this died before pupating.

Despite our inability to discover fly-infested host fruits in the lowlands, we found *Carpophthoromyia n. sp.* to be very numerous along roads and in forest clearings about Douala. This fly is identical with the single specimen taken at Olokemeji, Nigeria, and with that bred from Conopharyngia at Yaoundé. Another species taken in the forest near Douala was *Ceratitis cosyra.*

Belgian Congo

(July 2-6, 1936)

The lower Congo valley, at least for the 80 miles from the sea to Matadi, is a semi-arid country unfavorable for finding fly-infested fruits. During a stopover at Matadi the only infested fruits to be found were a handful of Momordica taken in a native garden some 20 miles south of the river. From these was bred a new species of Dacus near *chrysomphalus* Bezzi, but no parasites. Although the Belgian Congo has not been studied intensively for fruit flies, it is an extremely rich country entomologically, and investigation of its forest fruits for fly parasites should be profitable.

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
SEPTEMBER 16, 1936, TO DECEMBER 10, 1936.

Date	Per Pound	Per Ton	Remarks
Sept. 16, 1936......	3.61¢	$72.20	Cubas.
" 17	3.555	71.10	Puerto Ricos, 3.55; Cubas, 3.56.
" 18	3.505	70.10	Puerto Ricos, 3.50; Cubas, 3.51.
" 21	3.50	70.00	Various raws ex store.
" 22	3.46	69.20	Various, 3.45; Cubas, 3.46; Philippines, 3.47.
" 23	3.405	68.10	Cubas.
Oct. 1	3.40	68.00	Philippines.
" 2	3.35	67.00	Puerto Ricos, Philippines.
" 13	3.375	67.50	Philippines, 3.35, 3.40.
" 14	3.36	67.20	Cubas, 3.35; Philippines, 3.36, 3.37.
" 15	3.35	67.00	Cubas.
" 19	3.40	68.00	Philippines.
" 21	3.39	67.80	Puerto Ricos.
" 29	3.355	67.10	Puerto Ricos, 3.35; Philippines, 3.35, 3.36.
Nov. 2	3.40	68.00	Philippines.
" 4	3.55	71.00	Philippines, 3.50, 3.55, 3.60.
" 5	3.65	73.00	Puerto Ricos.
" 6	3.69	73.80	Cubas, 3.68; Philippines, 3.70.
" 16	3.65	73.00	Cubas, Philippines.
" 18	3.70	74.00	Philippines.
Dec. 1	3.85	77.00	Cubas.
" 2	3.81	76.20	Cubas.
" 10	3.78	75.60	Cubas.